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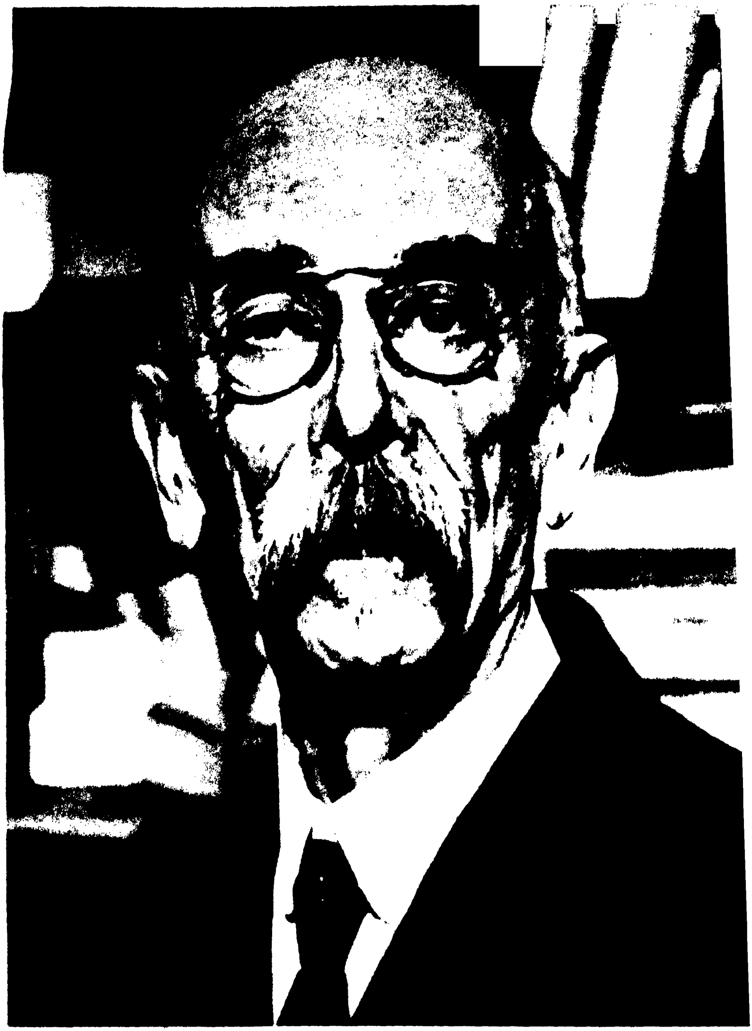
# DIATHERMY



ARSÈNE D'ARSONVAL

*Emeritus Professor of Medicine,*
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The masterly researches of this distinguished pioneer laid the foundations on which the present-day electrothermic methods of treatment are based. This portrait was made in 1932 when he was elected Emeritus Professor on the completion of fifty years' research at the Collège and thirty-eight years' service as Professor. (Portrait reproduced by courtesy of *Archives of Physical Therapy, X-ray, Radium*, December, 1932.)

[*Frontispiece.*

# DIATHERMY

## INCLUDING DIATHERMOTHERAPY AND OTHER FORMS OF MEDICAL AND SURGICAL ELECTROTHERMIC TREATMENT

BY

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# PREFACE TO THE THIRD EDITION

THE advance in knowledge of diathermy and diathermotherapy and the progress that has been made in the surgical uses of high-frequency currents have rendered it necessary to compile a new and enlarged volume on the subject. The increase in size is due in part to the addition of introductory accounts of short-wave and inductothermic treatment. Their kinship to diathermotherapy is close ; and the writer believes that it would be helpful to those who are unacquainted with these forms of treatment to include a brief account of them in a book that deals with the parent method.

The large amount of clinical experience that has been acquired in the use of the diathermic current for the surgical and non-surgical treatment of diseases of the *special regions*, and the increasing employment of the cutting arc, render it no longer possible for one worker to write with authority on all of these regions or describe the results that may be expected to follow each form of treatment. For this reason the writer has sought the assistance of other workers who have been kind enough to contribute chapters on the subjects of which their knowledge and experience are known to be wide. Mr. A. H. Burgess has written on the use of the cutting arc in general surgery, and Mr. Douglas Harmer has described the use of diathermy in the surgical treatment of malignant disease of the upper air passages. Mr. Kenneth M. Walker has written on the surgical treatment of the enlarged prostate. The use of diathermy in medical and surgical ophthalmology has been described by Mr. H. B. Stallard. Dr. C. A. Robinson has contributed two chapters on the employment of diathermy in gynæcology and in the treatment of chronic arthritis. Dr. H. Wallace Jones has written on the treatment of diseases of the cardiovascular system by diathermy and short waves. Dr. Norman Bell Graham has described his experience in the treatment of dementia paralytica by procuring therapeutic fever. The late Dr. Dan McKenzie was the author of the chapter on the use of diathermy for the destruction of tonsils.

Adequate knowledge of the physics of high-frequency currents must be obtained before much can be understood of the production and properties of these currents, or even the meaning of terms. This is especially the case in regard to the currents of enormously high frequency that are employed in short-wave and inductothermic treatment. The task of writing on this subject, properly relegated to a physicist, has been undertaken by H. J. Taylor, whose investigations on the biological properties of ultra-high-frequency currents are beginning to shed light on a difficult and perplexing subject.

All the forms of treatment considered in the present edition have one feature in common: they are conducted by means of currents that oscillate with high frequency. The employment of one of these currents for the production of diathermy and its use for medical and surgical purposes formed the main topic of the original edition. To the second edition was added an account of the use of high-frequency currents for killing pathological tissue by means of sparks, and excising it by means of a cutting arc. The present edition deals also with short-wave and inductothermic treatment, and a few pages have been written on the remaining form—one in which an electric effluve or sparks from vacuum electrodes are used. It has been included not merely to render the list complete. Though some would regard it only as a display of high-frequency fireworks, it is nevertheless a rational form of treatment; its *modus operandi* is not obscure, and it has a small field of therapeutic usefulness.

In spite of these additions the original title has been retained for the present edition, although it will be realised that the word *diathermy* cannot accurately be used in association with every form of treatment conducted by means of high-frequency currents. Their inclusion under the general heading "*electrothermic methods*" is suggested because all of them are forms of treatment by means of heat, and in each one the heat is generated by means of electricity.

In the endeavour to obtain standardisation of nomenclature the terms *electrodesiccation, electrocoagulation* and *electrosection* have been used throughout the present edition for the three *surgical* forms of electrothermic treatment. In regard to the *medical* (non-surgical) forms the name *diathermy* now is universally used in connection with the best known variety, one of which the nature has been understood for the longest time—some twenty-five years. The newer form of medical electrothermic treatment retains the scarcely appropriate name of "*short-wave therapy*" which was originally given to it when the technique bore little resemblance to that which now is practised. The newest variety is termed *inductothermy*—a name which is appropriate because the heat is produced by induced high-frequency currents.

The death within the last two years of three distinguished workers—two of whom may well be regarded as pioneers—induced the writer to include their portraits in this edition as a small posthumous token of regard for their work and the influence it exercised on the progress of electrothermic surgery. John Anderson was the surgeon in this country who transformed the original crude method of cutting by an electric arc into the elegant present-day operation of *electrosection.* The equally crude method of treating malignant growths by means of sparks underwent a similar transformation in the hands of the United States surgeon, William Lawrence Clark, and the outcome was the operation known to-day as *electrodesiccation.* Dan McKenzie, one of the early workers in England on diathermy in surgery, made valuable contributions towards the progress of electrocoagulation in the treatment of diseases of the upper air passages. It has already been stated that the chapter in the present book on the treatment of infected tonsils by this method came from his pen.

The pioneer work of Arsène d'Arsonval, now in his eighty-sixth year, and Emeritus Professor at the Collège de France, laid the foundations on which the present-day electrothermic methods are based. His portrait has been made the frontispiece of the present book.

The writer takes this occasion to express his obligation and thanks to those who have rendered help by the contribution of chapters. A similar expression is tendered to *The Practitioner* for permission to quote from an article in their issue of July, 1935; to Henry Kimpton for allowing certain illustrations in the seventh edition of "The Essentials of Medical Electricity" to be reproduced in the present book; to *The Lancet* and the *British Medical Journal* for the loan of blocks; to the *Archives of Physical Therapy, X-Rays, Radium* for permission to copy the portraits of Professor d'Arsonval and W. L. Clark that appeared in their issues of December, 1932, and January, 1936, respectively; and to The Medical Supply Association, Schall & Son, A. E. Dean & Co., Watson & Sons, Newton & Wright, Stanley Cox, Electro-Medical Supplies, F. W. Read & Sons, H. G. Fischer, John Weiss & Son, The Genito-Urinary Company, The General Radiological and Surgical Company, and The Victor X-Ray Corporation. These firms provided not merely the illustrations—many of which had to be specially prepared—but much additional information in regard to electrotechnical details of their apparatus.

E. P. CUMBERBATCH.

MANCHESTER SQUARE,
*March*, 1937.

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# PART I

## INTRODUCTION TO THE ELECTROTHERMIC METHODS. HISTORY: PHYSICAL AND ELECTROTECHNICAL PRINCIPLES

# CHAPTER I

# INTRODUCTION TO THE ELECTROTHERMIC METHODS OF TREATMENT

THERE are various ways of using electrical energy when it is desired to treat disease by means of heat. The simplest is one in which a pad, placed in contact with the body, is heated by means of an electric current. The body derives heat from the pad by the process of *conduction*. Another method is to utilise the current for heating a coil of wire placed at a distance from the body. In this way the body derives heat from the coil by *radiation*. Another procedure in which tissue is heated by conduction is witnessed when a platinum wire loop, heated to redness by an electric current, is thrust into pathological tissue for the purpose of destroying it.

These may be called *indirect* methods because the currents pass through, and heat, an external object placed in contact with the body, or near to it. The body itself is not in the circuit.

There are other ways of using electric currents for thermotherapeutic purposes. They differ in one essential particular from the indirect methods : *the body itself is in the circuit of the current that produces the heat.* They may therefore be called *direct* methods. These direct methods and their uses in medicine and surgery form the topic of the present volume.

In their practise it is necessary to employ currents of a special kind, because the voltage or the amperage attains much higher values than the maximum permissible when currents like the galvanic, sinusoidal, etc., are passed through the body. The currents utilised in the *direct* methods are those that oscillate at an extremely high rate ; they are the so-called " high-frequency " currents. Unlike the galvanic current they do not produce chemical (electrolytic) changes in the tissues and they do not possess the stimulating properties of currents like the faradic or sinusoidal.

There are various ways of utilising high-frequency currents for producing heat for the purpose of treatment. In one method a pair of electrodes are applied to the body and placed in the circuit of a high-frequency current that attains an intensity high enough to raise the temperature of the parts between the electrodes. In another method the body is placed close to a coil of wire in which a high-frequency current is oscillating. The current induces other high-frequency currents in the body. These induced currents are strong enough to heat the tissues.

In both of these methods the heat that is used for therapeutic purposes is generated *inside* the body. They may therefore be termed *endogenous* electrothermic methods.

There are other ways of employing high-frequency currents for thermotherapeutic purposes. One electrode, a metal plate, is placed in contact with the body. It is an indifferent electrode and merely serves the purpose of bringing the body into the circuit. The other electrode is a needle or fine wire. It is not in contact with the body but separated from it by an air space. The current can be made to pass across the air space, either in the form of an electric brush or long thin sparks, or in the form of short thick sparks or an electric arc. The form in which it passes is determined by the length of the air space and the voltage of the source of supply of the current.

In these methods the heat that is used for treatment is derived from the brush, the sparks or the arc. It is generated *outside* the body. They may therefore be called *exogenous* electrothermic methods.

Various kinds of treatment, surgical as well as medical, can be conducted, some by the endogenous and others by the exogenous methods. The same current is not suitable, or not equally suitable, for each form of treatment. This reason, and the fact that there is much confusion in regard to nomenclature, render it advisable to give a brief introductory account of each of the electrothermic methods and the forms of treatment conducted by them.

## I

## The Endogenous Methods and the Forms of Treatment Conducted by them

(1) The most widely employed of these methods is one in which the part of the body to be treated is included between a pair of electrodes which make contact with the body. The frequency of oscillation of the current has a minimum value of about 500,000 cycles per second. If it is much lower the current will regain some of its power to stimulate, especially when it reaches a high amperage. Some of the generators employed in the practise of this method provide currents that oscillate with frequencies higher than that stated. The frequency may have a value of 1,500,000 or 2,000,000 cycles per second. The heat produced in the tissues is called *diathermy*. This name will be reserved for the heat generated in the body by currents that oscillate with frequencies *ranging between* 500,000 *and* 2,000,000 *cycles per second*. The method will be called the *diathermic* method, and the treatment conducted by its means will be called *diathermic treatment* or *diathermotherapy*.

Two forms of treatment are conducted by means of diathermy. One is medical and the other surgical.

In *medical* diathermic treatment the region to be treated is subjected to a degree of heat insufficient to kill the tissues or impair their vitality. Medical diathermy is considered in Part II, Section I.

In *surgical* diathermic treatment, abnormal tissue is subjected to a degree of heat high enough to coagulate it *en masse*. Surgical diathermy is sometimes called *diathermic coagulation* or *electrocoagulation*. It is considered in Part III.

(2) During the past seven years increasing use has been made of an electrothermic method which has some resemblance to that just described. It is conducted, however, in a somewhat different manner. The metal portions of the electrodes are separated from the body by some non-

conducting material. In addition, the currents oscillate with much higher frequencies, ranging between 10,000,000 (ten million) and 100,000,000 (one hundred million) cycles per second. Various names have been given to the heat that is generated in the tissues, such as *short-wave diathermy*, *parathermy*, *radiathermy*, *neodiathermy* and *dielectrothermy*. Most writers believe that the treatment is wholly thermic in nature. A few maintain that its effects cannot entirely be attributed to the action of heat. Until we know more of the distribution of the heat in the body it will avoid confusion if the non-committing expression *short-wave*[1] *treatment* is used. In the present volume it will be reserved for that form of treatment in which the body is included between a pair of electrodes and placed on the path of currents oscillating with frequencies ranging between 10,000,000 and 100,000,000 cycles per second. The subject of short-wave treatment is considered in Part II (Section III).

(3) The most recent of the methods employed for the production of heat within the body is one in which no electrodes are used. The generator produces a current which oscillates with a frequency of about 12,000,000 cycles per second. A thickly insulated flexible cable is coiled around the part of the body to be treated, and its ends are connected to the generator. Alternatively, the cable may be made to assume the form of a flat coil which is placed adjacent to the part requiring treatment. The current in the coil induces others of the same frequency in the body, and they attain an intensity sufficient to heat the tissues. The name *inductothermy* has been given to the heat generated in the body in this way. It indicates that the heat is generated by means of *induced* currents. It does not imply any special distribution of temperature. The qualification *inductothermic* may be applied to the treatment and the method by which it is conducted. The subject is considered in Part II (Section IV).

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[1] The reason for the use of the qualification "short-wave" is the following: the electromagnetic waves emitted from circuits in which currents are oscillating with the enormously high frequencies used in the treatment are short in comparison with those emitted by the currents of less high frequency than are used in diathermic treatment.

## II

## The Exogenous Electrothermic Methods and the Forms of Treatment Conducted by them

(1) The oldest of these methods is one in which the body is included in the circuit, and the part to be treated is separated from the pointed active electrode by a space of some inches. The current passes across the space in the form of long thin sparks. If the space is just too wide for the passage of sparks the current passes in the form of an electric brush—the so-called "effluve" In order that there may be a passage of current across spaces of these widths the voltage must be very much higher than that needed for producing a diathermic current. By reason of the great resistance of the air spaces the strength of the current is reduced to a negligibly low value. It is not necessary for the current to oscillate with high frequency. A non-oscillatory (unidirectional) current would be equally suitable.

The electric brush, or *effluve*, as it is usually called, heats numberless spots of the epidermis on which it is directed. The spots are ultra-microscopic or even molecular in size. The end-organs of the afferent nerves under the epidermis are stimulated. The stimulation is *thermic* rather than electrical. The name "*effluvation*" is given to a form of treatment in which the electric brush or effluve is employed.

The action of *thin* sparks is similar to that of an effluve but it is more intense. The spots they heat are less minute and they stimulate the sensory nerve endings more strongly. Treatment by means of sparks that are too thin to inflict damage on the skin is sometines known as "*étincellage.*"

These forms of treatment are not so often employed now as in former days. They are considered in Part II. (Section II).

(2) The forms of treatment noted above are non-surgical in nature; the heat derived from the sparks or effluve is insufficient to kill the tissue on which they are directed. Sparks also are employed in the form of treatment now to be considered. They are shorter but thicker than those

utilised in étincellage and they heat the tissue on which they fall to a degree high enough to kill it. Killing abnormal tissue in this way constitutes a *surgical* form of electrothermic treatment known as "fulguration" or "electrodesiccation." It is considered in Part III.

In this form of treatment the current that produces the sparks must oscillate with high frequency. The voltage is often higher than that which produces a diathermic current.

(3) By making the air space between the body and electrode very narrow it is possible for the current to pass across the gap in the form of an electric arc. The electrode is a thin needle or fine wire. The arc enables the electrode to be introduced into the body and moved forwards or backwards or in any direction without effort because it forms a thin film around the metal and divides or "cuts" the tissue ahead of it.[1] The use of an arc in place of a scalpel for cutting tissue is known as *electrosection*. An operation in which the arc is used for this purpose was formerly termed an "*arc-operation*." (Part III.)

The voltage used for the production of this "cutting arc" is lower than that utilised for producing a diathermic current, but the frequency of the oscillation is higher, viz., about 5,000,000 cycles per second.

In all the forms of treatment mentioned above the effects brought about by the current—whether medical or surgical—can rationally be attributed to the action of heat. For this reason the various ways of utilising high-frequency currents in the treatment of disease, and the forms of treatment conducted by them, may be termed *electrothermic*. The additional qualification *direct* will serve to distinguish them from those in which an electric current is employed solely for the purpose of heating some external object which is placed in contact with the body or at some distance from it. But when the expression *electrothermic* is used without any qualification it is generally understood to refer to the *direct* methods—those in which the body itself is included in the circuit of the current that generates the heat.

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[1] Since the arc is *within* the tissues it might be thought that this method should be included among those in which the heat is generated *within* the body (endogenous heat). As a matter of fact the arc first appears *outside* the body, and when the electrode is inserted it is not in precise contact with the tissues.

The expression "high-frequency treatment" was commonly heard in the early days of the empirical use of the currents, and even to-day it is often used as a name for treatment by an effluve or non-cauterising sparks. It should, however, be discarded because it gives no information as to the nature of the treatment and causes confusion with the other forms of treatment in which high-frequency currents are employed.

The word "high-frequency" should be used solely as the family name for the currents employed in the different forms of treatment conducted by them.

| Method. | | Treatment. | |
|---|---|---|---|
| | | *Medical.* | *Surgical.* |
| *Body in circuit and heat generated within tissues (endogenous heat).* | Heating the tissues by currents of which the frequency ranges between 500,000 and 2,000,000 cycles per second. | Medical diathermic treatment (medical diathermotherapy). | Diathermic coagulation (electro-coagulation). |
| | Heating the tissues by currents of which the frequency ranges between 10,000,000 and 100,000,000 cycles per second. | Short-wave treatment. | |
| | Heating the body by *induced* currents having a frequency of 12,000,000 cycles per second. | Inductothermic treatment. | |
| *Body in circuit and heat generated outside tissues (exogenous heat).* | Heating the surface of the body by an effluve (electric brush). | Effluvation. | |
| | Heating the surface of the body by non-cauterising sparks. | Étincellage. | |
| | Heating superficial pathological tissue by cauterising sparks. | — | Fulguration or electrodesiccation. |
| | Cutting tissue by heat derived from an electric arc. | | Electrosection. |

The different forms of direct electrothermic treatment and the names that will be given to them in the subsequent pages are tabulated on p. 9. Other names, not in general use, that have been suggested from time to time will be mentioned in the sections dealing with the various electrothermic methods.

Of the different forms of electrothermic treatment, medical diathermotherapy is the one which is most widely employed and has established the largest therapeutic field. The field claimed for short-wave treatment is as large, but its boundaries are not yet defined because the method has not been in use for a sufficient time and a wide experience has been gained by very few workers. Inductothermy is the most recent addition to the electrothermic armamentarium. It seems to be the most efficient electrothermic agent for elevating the temperature of the entire body and obtaining the so-called " therapeutic fever." As far as local treatment is concerned, the inductothermic method is under trial and it is too soon to compare its therapeutic results with those obtained by the diathermic or short-wave method.

In regard to the surgical electrothermic methods it may be said that diathermic coagulation has established its value but is less frequently employed at the present time on account of the popularity of radium. Electrodesiccation is widely employed by surgeons in the United States. Its value is beginning to obtain recognition in England. The same may be said of electrosection.

# CHAPTER II

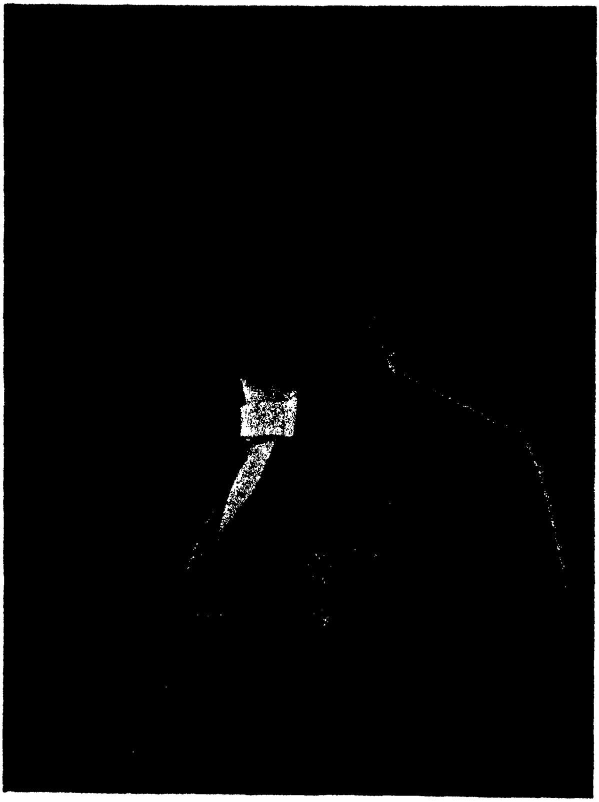
## HISTORY OF THE EVOLUTION OF DIATHERMOTHERAPY FROM THE STUDY OF HIGH-FREQUENCY CURRENTS

It was not until the recognition of the nature of diathermy that high-frequency currents began to be employed rationally or scientifically for medical and surgical purposes. In the present chapter a brief account will be given of the studies which finally led to the establishment of diathermotherapy.

The scientific study of the discharge of the Leyden jar was the origin of the discovery of high-frequency currents. The fact that the current accompanying the discharge might be alternating, instead of unidirectional, was deduced by Joseph Henry, of Washington, who wrote a memoir on the subject in 1842. In 1853 Professor William Thomson (afterwards Lord Kelvin) made a communication on the subject and stated the conditions which determined whether the current would be alternating or unidirectional. The conditions which decided the *frequency* of the alternation were afterwards ascertained, and it was calculated that the frequency might be thousands or even millions per second.

It was not until 1890, however, that any inquiry was made in order to ascertain the effects which high-frequency currents might have on the living tissues. Professor d'Arsonval, at the Collège de France, Paris, showed that the power of an electric current to stimulate muscle and nerve became progressively feebler when the frequency of its alternation exceeded 5,000 times per second. When the frequency exceeded 10,000 the muscles did not contract at all. In the same year d'Arsonval employed currents of much higher frequency (alternating more than a million times per second) and found that they were unable to cause contraction of muscle. This work was communicated to the *Société de Biologie in 1891.*

Since the high-frequency currents which he first employed were of low intensity, d'Arsonval proceeded to experiment with apparatus providing currents of greater strength. In April, 1892, he made his famous demonstration. Two electrodes were connected to the apparatus.



An earlier portrait of Professor A. d'Arsonval.

With one hand d'Arsonval grasped one of the electrodes. Another experimenter (Cornu) grasped the other. A filament lamp, needing a current of 1 ampere, was placed in the circuit. One of its terminals was connected to a metal rod, which was grasped by the other hand of d'Arsonval. The other terminal was similarly brought into connection with the disengaged hand of Cornu. The apparatus was set in operation. The filament of the lamp became incandescent. Although a high-frequency current of no less than an ampere was passing through the bodies of the experimenters the only sensation they felt was that of warmth in the wrists.[1]

D'Arsonval afterwards employed still stronger high-frequency currents. He showed that if the body were connected to the generator by way of electrodes grasped in the hands and the current passed for some time there was a general feeling of heat accompanied by profuse perspiration.

From 1892 onwards, d'Arsonval made a number of most important experiments in order to ascertain the biological properties of high-frequency currents. He showed that they were able to increase the respiratory exchange and the output of nitrogenous bodies and phosphates in the urine.

He showed that they could cause dilatation of the peripheral vessels, and sometimes lower the arterial blood-pressure. He also noted that they could increase the output of heat from the body. Experimenting on himself in 1895 he found that the output of heat in fifteen minutes increased from 79·4 to 127·4 calories.

In 1896 Professor d'Arsonval showed that the passage of a strong high-frequency current along the hind limbs of a rabbit deprived them of life. They became gangrenous and separated from the body.[2]

In 1898 he began to investigate the action of high-frequency currents in disease. He found that they possessed therapeutic properties in certain disorders of the circulatory system. The heat felt by the patients during treatment did not escape his notice. He called attention to the feeling of unpleasant heat ("*chaleur désagréable*") which they sometimes experienced, and he wrote on the necessity of avoiding it. (*"Il faut éviter toute élevation anormale de temperature."*)

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[1] Currents of other kinds are capable of killing even large animals when their strength reaches half an ampere.

[2] Similar experiments were performed by Bordier and Lecomte in 1900. The current was directed through the entire body of a rabbit by way of electrodes introduced into the mouth and rectum. The rate of respiration gradually increased and became so rapid that it could not be counted. The heart beat became imperceptible, and the animal died, the tissue proteins being coagulated.

It is evident, therefore, that d'Arsonval was the originator of the treatment which is now known as *diathermotherapy*. He employed high-frequency currents of high intensity, and there is no doubt that they heated the tissues through-and-through.

The importance of the heat, and its *distribution*, however, were not realised, and the way in which the heat was produced was not clearly understood. It was thought to be the result of excessive katobolism. The belief was held that the current was restricted to the surface of the body. This belief, now known to be erroneous, was taken to furnish the reason why high-frequency currents were unable to stimulate the nerves or produce contraction of muscles.

At the commencement of the present century, treatment by " high frequency " began to be popular in France. The apparatus used was far less powerful than that employed by d'Arsonval and the currents yielded an insignificant amount of heat. This was doubtless due to the belief that the biological effects brought about by high-frequency currents were due to some action other than that of heat. After a couple of years the treatment began to fall into disrepute. Even if the high-frequency currents had been capable of producing large amounts of heat, like those employed by d'Arsonval, the lack of knowledge of their *modus operandi* would have rendered the treatment empirical and its progress infinitely slow.

In Germany this " high-frequency treatment " was viewed with scepticism, and any effect it had on the patient was attributed to the influence of the machine on the mind.

In England the treatment was tried by various workers. It was regarded with favour by a few. Many were sceptical. Writing in 1906 the late Dr. Lewis Jones expressed the following views. " There is no doubt that high-frequency treatment exercises an influence upon the course of a certain number of morbid states, although in many of these its influence for good is not of any particular degree of excellence."

It is to German and Austrian workers that we are indebted for the interpretation—which is now regarded by most authorities as correct—of the action and effects of high-frequency currents on the body. As far back as 1899 von Zeynek, in a paper in the *Göttinger Annalen* on the excitability of the sensory nerve endings to alternating currents, made a brief allusion to the heating-through ("*durchwarmung*") of the finger tips by high-frequency currents and interpreted the phenomenon as a consequence of the well-known principle that conductors can be heated by passing electric currents through them.

To von Zeynek, therefore, must be accorded the honour of being the first to give the correct explanation of a phenomenon which had long been obscure. He observed that the tissues could be heated by high-frequency currents ; he maintained that the heat was produced by the currents in overcoming resistance, and he concluded that the heat was distributed *through* the tissues.

There appears to be no further communication on the heating of tissues by high-frequency currents until 1907. In September of that year, Nagelschmidt, who had been experimenting with high-frequency currents, gave a demonstration in Dresden, at the Congress of Naturalists, of the heating of the arms and chest of a man by means of these currents. He spoke of the *penetration* of the heat (thermopenetration) and advised the treatment of diseases of the joints and the circulatory system by the same method.

In February, 1908, von Berndt and von Preiss, in conjunction with von Zeynek, published a paper on the treatment of diseases of joints by high-frequency currents. It is interesting to note that they spoke of "*thermopenetration*" as the essential part of the action of these currents.

When the importance of the production of heat was realised, further attention was paid to the design of machines for producing high-frequency currents. At the Congress held at Budapest in 1908, Nagelschmidt showed a machine which yielded currents capable of producing a much larger quantity of heat and a higher temperature. In 1909 he proposed the name *diathermy* in preference to "thermopenetration" ; the latter term had been used by von Zeynek.

It is uncertain who was the *first* to utilise high-frequency currents in disease *with the intention of heating the tissues through-and-through and obtaining the therapeutic effects of heat.* Nagelschmidt and von Berndt both employed the currents for the purpose above-stated and worked independently of each other, the former in Berlin, and the latter in Vienna.

Precisely similar treatment had been demonstrated in the laboratory a decade earlier by d'Arsonval, but it was not until 1914 that the employment of high-frequency currents was revived by the medical profession in France. More efficient machines were constructed, and the treatment was called *diathermothérapie.*

Diathermic treatment was introduced into England in 1909 by Lewis Jones when he was Medical Officer in charge of the Electrical Department of St. Bartholomew's Hospital. In the following year he invited Nagelschmidt to give a demonstration of surgical diathermy in London. Three cases were provided by W. Douglas Harmer, now Consulting Surgeon to the Department of Laryngology of the same hospital. One was a case of pulsating nævus on the floor of the mouth, another was one of epithelioma of the palate, and the third was a case of enlarged tonsils. Nagelschmidt treated them by surgical diathermy in the Electrical Department of St. Bartholomew's Hospital on October 21, 1910. This was the first occasion of the use of diathermy in surgery in England.

After its introduction into this country more attention was paid by English workers to its *surgical*, than its medical, uses. W. D. Harmer was the first to realise its value in surgery and to employ it in the treatment of malignant disease of the mouth and throat. Other laryngological surgeons in London and England followed, and after a few years the use of surgical diathermy in disease of the regions mentioned was more extensive in this country than in other parts of Europe. In recent years, however, it has been less employed, probably on account of the prominent position occupied by radium in the treatment of malignant disease, and the increasing use of electrosection. The progress of medical diathermy was slow at first in this country. It was practised by few and prescribed for helpless and intractable cases of arthritis. Its value, however, was established in the Great European War. In the years that followed, the therapeutic field of medical diathermy gradually widened. To-day there is no system of the body without one disease at least which can advantageously be treated by diathermy, and there is no civilised country where diathermotherapy is not practised, and there are few towns of importance where it is not available.

The first two text-books on diathermy appeared in 1913. One was Nagelschmidt's "Lehrbuch der Diathermie." The other, entitled "Diathermie," was written by Kowarschik, of Vienna. In England a series of articles on medical and surgical diathermy was written by the author for the *Archives of the Röntgen Ray* (now the *British Journal of Radiology*), the first appearing in July, 1914. These articles formed the nucleus of the first edition of the present book.

In France, the first book on the subject ("Diathermie et Diathermothérapie") was written by Professor Bordier, of Lyons, and published in 1922.

The employment of sparks for killing abnormal tissue was first described by Oudin, of Paris, as far back as 1894. It is the oldest of the surgical electrothermic methods. But it was not until 1911 that its value began to obtain recognition after improvement of the technique and additional investigation, mainly by W. L. Clark, of Philadelphia. The year 1910 saw the commencement of the use of an electric arc for the purpose of cutting tissue. The pioneer work was conducted by Eitner, of Vienna, and Czerney, of Heidelberg. The method was little used, however, before 1924. In that year G. A. Wyeth, of New York, described his modification of the original apparatus and method. His subsequent investigations and those that were conducted independently by John Anderson, of Dundee, were the beginnings of the forward progress of the surgical method now known as electrosection. Treatment by the "short-wave" method was first practised in 1929 by Schliephake, of Jena, although the first investigation of the action of short-waves on animals was conducted in 1926 by Schereschewsky, in the United States. The method to which the name " inductothermic " has been given has quite recently been introduced. Here, again, the principle on which it is based and its application for treatment were orginally devised by d'Arsonval during the last decade of last century.

Additional notes on the history of the methods above mentioned will be found in the sections that deal with the different forms of electrothermic treatment. From the account already given it is evident that France, Germany, Austria, Great Britain and the United States have made contributions of importance towards the development of the electrothermic methods and their uses for treatment. In each method it is interesting to observe the fact that the pioneer work was conducted in one country and its subsequent development in another.

# CHAPTER III

## PHYSICAL PRINCIPLES

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MODERN developments in the use of the high-frequency current for the production of heat in the body require the physician to be more and more versed in electrotechnical principles; and it is essential that, for the maximum utility to be achieved, a sound knowledge of the physical basis of the method he employs should be obtained. It is the intention of the writer, with the limited space at his disposal, to bring out the main features in an orderly manner. A certain knowledge of physics will be taken for granted.

A positively charged body is one whose atoms have a deficit of electrons; conversely a negatively charged body is one whose atoms have an excess of electrons. When bodies in this state are connected by a conductor, electrons flow from the negative to the positive, to equalise the distribution. This flow of electrons from the negative to the positive constitutes the flow of an electric current. The old idea, and the one upon which the nomenclature of the subject is founded, is that "electricity" flows from the positive to the negative. Charged bodies exert forces of attraction and repulsion; like charges repel, and unlike charges attract. Thus, if a positively charged body is placed in an atmosphere containing positive ions it will repel them, but if placed in an atmosphere containing electrons or negative ions these will be attracted and the positively charged body has its charge neutralised.

There are three types of electric current :—

(1) Conduction currents.
(2) Displacement currents.
(3) Convection currents.

**Conduction currents** are those which are due to the passage of electrons along a conductor, such as a piece of metal wire ; the electrons being handed along the conductor from one atom to another.

**Displacement Currents.** In materials where the number of electrons free to move from one atom to another is negligibly small, the conduction current is also negligibly small. Such substances are called insulators. Consider, however, such a tightly bound electron revolving round its nucleus in a circular path (Fig. 1), and now consider it when a voltage is applied. The electron will be attracted towards the positive pole, but will still revolve round its nucleus ; it will traverse a path similar to that shown diagrammatically in Fig. 1A.

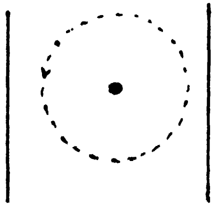


Fig. 1.

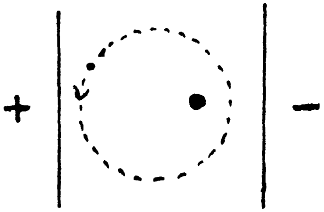


Fig. 1A.

If the applied voltage remains steady, the pull on the electron is constant, and no current flows in the material. At the moment the voltage is switched on, however, the electron will be displaced, and a momentary displacement current set up as it finds its new orbit. If an alternating voltage is applied instead of a constant voltage the electrons will not have time to settle into a constant state, but will be constantly readjusting their orbits. In other words, there is always a displacement current in the material, and it will be seen that the frequency of alternation of the applied voltage will affect the magnitude of this displacement current.

If the applied voltage increases in magnitude it may reach a point where it is enough to draw the electron away from the attraction of its nucleus. When this happens a conduction current results, and the insulation of the material breaks down.

**Convection Current.** This type of current is due to the movement of ions, positive or negative, or electrons, in a gas, a liquid or a vacuum. Such a current will be met with later when the thermionic valve is discussed.

## ELECTRIC FIELD

This term is used to describe the interaction of electrified bodies. The field is no more than a name for the space surrounding a charged body, and a knowledge of the field is bound up in the knowledge of how a second charged body (having so small a charge that it does not disturb the field itself) is acted upon by the neighbouring charge or charges. The field is looked upon as a system of strains set up in the "ether" which is supposed to fill all space. This system of strains is supposed to exist whether there is a charged body upon which it can act or not. The experimental fact about charged bodies is that they attract and repel one another. That is, they exert forces even when separated in a vacuum. If we draw a diagram to represent the paths along which a charged sphere will attract a movable one bearing a charge of opposite sign from various points in its vicinity we get a series of lines converging towards the centre of the fixed sphere (Fig. 2). These lines are called lines of force.

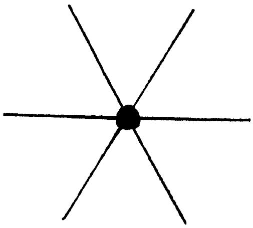


FIG. 2.

The plates of a charged condenser are said to produce a condenser field between them. This field is used in the application of ultra-high-frequency currents to the body by the condenser field method. This subject will be further enlarged upon when these ultra-high-frequency currents are considered.

**Electro-statics.** Suppose an electric charge in quantity Q is placed on a material and this raises its potential from zero to a value U, then the ratio of Q/U is called its "electrical capacity." The effect of bringing two conductors near to one another is to diminish the potential difference between them while leaving the magnitude of their charges unchanged ; its effect must also be to increase the effective capacities of both conductors. The arrangement of conductors whereby two opposite charges may be brought close to one another is known as an electric condenser. The commonest form of a condenser consists of two parallel metal plates with some dielectric between them. The space between the plates of the condenser plays an integral part in determining the capacity.

The capacity of a conductor is defined by the amount of charge necessary to raise it to any given potential. A conductor is said to have a capacity of one farad when a charge of one coulomb raises its potential by one volt. This is usually too large for convenience, and as a rule capacities are expressed in terms of microfarads, which are equal to one millionth of a farad.

METHODS OF CONNECTING CAPACITIES. (*a*) *In series.*

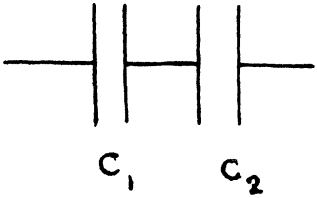
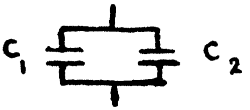


FIG. 3.

Let $c_1$ and $c_2$ be the capacities of two condensers connected in series. Let C be the capacity of the condenser to be equivalent, then $\frac{1}{C} = \frac{1}{c_1} + \frac{1}{c_2}$.

(*b*) *In parallel.*



$C = c_1 + c_2$.

FIG. 4.

While the question of connections is being discussed it may be as well to introduce the methods of connecting *resistances.*

(*a*) *In series.*

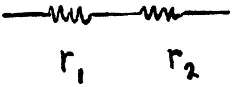
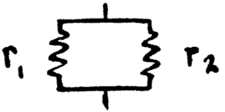


FIG. 5.

Let R be the equivalent resistance for $r_1 + r_2$.

Then $R = r_1 + r_2$.

(*b*) *In parallel.*



$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}.$$

FIG. 6.

Suppose two circular metal plates are charged to a certain potential difference from the D.C. mains, say 200 volts. They are then disconnected from the mains. The P.D. of 200 volts remains. If now a plate of some insulating material, say vulcanite, is placed between them, the potential difference between the plates falls, it may be to 100 volts. If the vulcanite is then removed the P.D. returns to its former value. The ratio of the capacity of the condenser with the insulating material between the plates to its capacity with air between the plates, the plates remaining at the same distance apart in each case, is called the dielectric constant or specific inductive capacity of the insulating material.

The difference between putting a conductor in the space between two condenser plates may be explained in the following manner :—

Let AB, CD and $A_1B_1$, $C_1D_1$ be two similar condensers.

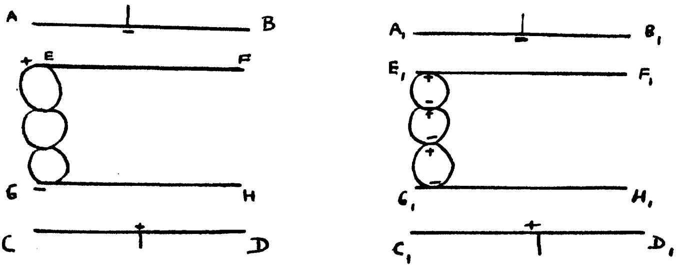


FIG. 7.

Let EFGH be a piece of metallic conductor and $E_1F_1G_1H_1$ be a piece of dielectric of similar size.

Let CD and $C_1D_1$ be the positive plates of the condensers. The surface GH will acquire a negative charge by the attraction of electrons to the surface GH, and the surface EF will acquire a positive charge. The molecules inside the conductor EFGH will remain neutral. In the case of the dielectric, however, the electrons in each molecule are drawn towards the positive plate but do not leave the molecule ; as explained before (p. 20), the electrons are not mobile, and each molecule acts as a separate individual. The following is a picture of what is happening :—

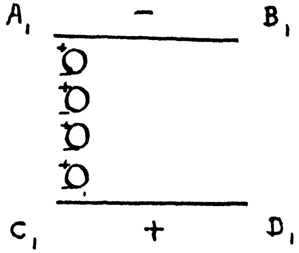


FIG. 8.

The electrons have been displaced within the separate molecules only. This effect is called the polarisation of the dielectric. With an alternating voltage applied to the condenser plates $A_1B_1C_1D_1$ the polarisation of the molecules changes with the change in applied E.M.F. This polarisation of the dielectric causes induced charges to appear at the two surfaces $E_1F_1G_1H_1$ of the dielectric as in the case of the conductor EFGH.

Consider now a condenser ABCD connected through a galvanometer G to a battery B and a switch S.

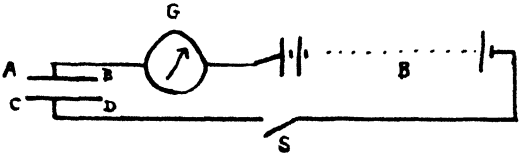


FIG. 9.

When the battery is switched on there will be an electron flow to the plate CD from the plate AB until the voltage between them is equal to the P.D. across the terminals of the battery. This will cause, as explained before, a momentary displacement current in the dielectric between ABCD. Suppose now that the battery is short circuited, and the switch closed ; there will be a rush of electrons from plate CD to plate AB, causing a deflection in the galvanometer, and the displaced electrons in the dielectric will return to their normal positions. Thus there will be a momentary conduction current round the circuit through the switch and galvanometer, and a momentary displacement current in the dielectric.

If a dielectric is a perfect one it should have no energy losses. This state is hardly ever attained in practice, however, there being nearly always some loss in the condenser. The main causes of loss of energy in a condenser are due to (*a*) conduction. In this case the dielectric material is not a perfect insulator and loss occurs by conduction through it. Losses also occur owing to the resistance of the leads to the condenser plates. (*b*) Dielection absorption. When a charge is put in a condenser the initial rush of current is followed by a smaller and more gradual one, which seems to be absorbed in the dielectric. Thus the time factor appears ; the charge given to the condenser is dependent on the time it is connected to the source of potential difference (P.D.). Also, when a condenser is discharged, the initial rush of current does not completely discharge it. If, after being short circuited for a short space of time, the condenser is put aside for a few minutes, another discharge can be obtained, but of course, not of the magnitude of the first discharge. This is due to the charge which is absorbed by the dielectric. If an alternating source of potential difference is applied to the condenser this dielectric absorption causes heat to be generated in it. The higher the frequency of the alternating P.D. applied, the smaller is the heat loss due to this cause, since the condenser does not have time to absorb completely before it is discharged. This gives the explanation of the drop of dielectric constant with increasing frequency.

It has already been mentioned that currents whose direction of flow changes periodically are found when a coil is rotated in a magnetic field. Currents undergoing similar variations are produced when a charged condenser is discharged through an inductance. These are known as oscillatory currents. Let C be a condenser and I an inductance (Fig. 10).

Suppose the condenser is charged ; as soon as contact is made with the inductance I then the condenser begins to discharge. Owing to self-inductance in the circuit the current does not reach its maximum at once but only increases gradually as the condenser discharges. It continues to flow even after the condenser is completely discharged. The condenser begins to be charged up in the opposite direction. If there are no electrical losses in the circuit (such as arise from the current flowing through a resistance) the condenser gradually acquires an equal and opposite charge to the one it has lost. In practice losses always occur, so that the acquired charge is always somewhat less. This process goes on until there is no charge left in the condenser. The current flowing is called an oscillatory current. The amplitude of the oscillations becomes less and less. An oscillation which dies away in this way is said to be damped. The time taken for one complete oscillation is independent of the amplitude of the oscillation. The number of oscillations per second is called the frequency ($f$). The time ($1/f$) for a complete oscillation to take place is dependent upon the capacity of the condenser and the inductance of the circuit. Both increase of inductance and capacity increase the time for a complete oscillation to take place, *i.e.*, decrease the frequency.

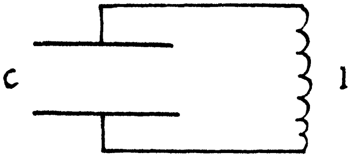


FIG. 10.

**Electro-Magnetism.** An electric current flowing in a wire, *i.e.*, electrons in motion, sets up a magnetic field round it. The lines of force of this magnetic field are in the form of concentric circles round the wire carrying the current. A circle of wire carrying a current whose direction is that of the arrow has a magnetic field round it as shown.

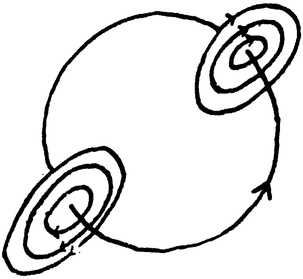


FIG. 11.

Now a coil of wire consists of a number of loops similar to the above, and the resultant magnetic field is due to the merging together of the lines of force of the separate loops (see diagram).

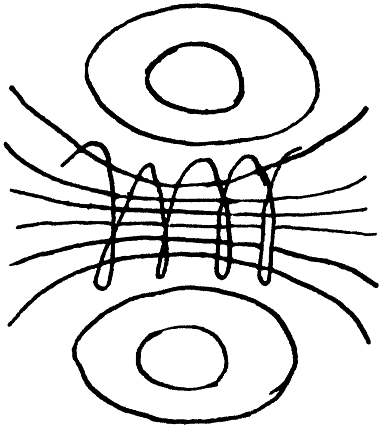


FIG. 12.

A coil of wire carrying a current and having a magnetic field as above is named a solenoid. If now we put another small coil of wire in the magnetic field of a solenoid and move it so that the number of magnetic lines of force is continually changing, then an electric current will be set up in the second coil. This phenomenon is called electromagnetic induction, and the current in our second moving solenoid is called an induced current. The magnitude of the induced electromotive force is proportional to the rate of change of the current, multiplied by the mutual inductance between the two circuits. Also a changing magnetic field in a conductor, due to changing current flowing, can cause an induced current in the conductor itself. This phenomenon is called self-induction. In general terms we say that the electric field produced by electro-magnetic induction is always in such a direction that it slows down the motion producing the induction. The unit of induction is called the henry, and (1) a circuit has a self-inductance of 1 henry if the E.M.F. induced in it is 1 volt when the current is changing at the rate of 1 ampere per second. (2) Two circuits have a mutual inductance of 1 henry if the E.M.F. induced in one of them is 1 volt when the current in the other is changing at the rate of 1 ampere per second. The resultant of the influences which oppose the flow of an alternating current is called the impedance. In the case of a steady direct current this is simply the resistance of the circuit, but in the case of alternating currents it is the combined effect of (1) the resistance; (2) an opposing back E.M.F., depending both on the self-inductance of the circuit, and upon the frequency; (3) when condensers are used, upon the electrostatic capacity.

With very high frequencies the current is confined entirely to the outer surface of the conductors, and the impedance becomes very great so that even short, thick wires behave as if possessed of very great resistance. On the other hand, inductive actions in dielectrics (displacement currents) occur more readily, so that with high frequencies the ordinary distinction between conductors and insulators becomes less marked.

The characteristic of alternating currents is that the direction in which they flow changes periodically. Currents of this kind are set up in coils rotated in a uniform magnetic field. These vary in intensity with the sine of the angle which the axis makes with the direction of the magnetic field. Currents with similar characteristics are produced when a charged condenser is discharged, through a coil having self-induction. Such currents are known as high-frequency oscillating currents, and they obey the same laws, if they follow the Sine Law, as low-frequency alternating currents.

Let V be the maximum voltage of an alternating current.

Let $v$ be the velocity at some time $t$.

Then the Sine Law says that

$$v = V \sin \omega t \text{ where } \omega = 2\pi \times \text{frequency}.$$

Consider a coil AB rotating in a magnetic field, M in the direction of the arrow, *i.e.*, at right angles to $NN^1$. When the coil lies in the direction $NN^1$ then no E.M.F. is generated in the coil; when it is in the direction $OO^1$ then the E.M.F. generated is at a maximum.

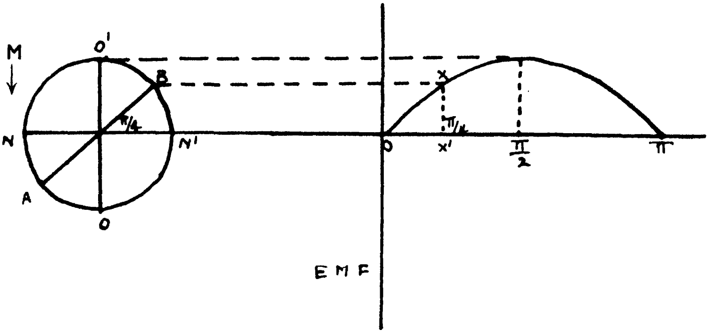


FIG. 13.

When the coil is in the position AB, when it has revolved through $\frac{\pi}{4}$ radians, the value of the E.M.F. is represented by $XX^1$. When the coil has made one complete revolution it has revolved through $2\pi$ radians and the E.M.F. curve then repeats itself. Hence we multiply the number of turns or fractions of a turn the coil has revolved by $2\pi$, then we get the angle the coil is making with $NN^1$, then we can get the sine of this angle. The value E at any instant is connected with its maximum value $E_0$ by the expression

$$E = E_0 \sin 2\pi nt.$$

$n$ = no. of revolutions of coil/second and $t$ the time in seconds or fractions of a second it has been revolving.

$2\pi n$ is usually denoted by $\omega$, where $\omega$ is called the angular velocity of the coil, *i.e.*,

$$E = E_0 \sin \omega t.$$

Suppose an E.M.F. is applied to a circuit so that the current produced in the circuit does not follow the E.M.F. but rises to its maximum some time after the application of the E.M.F. The current is said to lag behind the E.M.F.

Consider the curve of the voltage which follows the law $E = E_0 \sin \omega t$. Let this value be that at which the current generated is at its minimum and starting to rise. Then the current lags behind the voltage by the angle represented by $\omega t$, called $\phi$. This angle is called the phase angle. When $\phi = o$, the current and voltage are said to be in phase.

This is shown in the following figure.

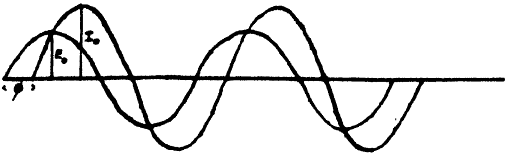


FIG. 14.

**Alternating Current Circuits.** (*a*) Alternating current flowing through a pure resistance R.

Let $C$ be the current at voltage $e$ and $I_0$ the current at maximum voltage. Let $E_0$ be the maximum current.

Then $\quad i = \dfrac{e}{R}$ and since $e = E_0 \sin \omega t$

$$i = \frac{E_0}{R} \sin \omega t = I_0 \sin \omega t.$$

(*b*) Alternating current flowing through an inductive circuit.

Let L be the self-inductance of the circuit.

Let $\dfrac{di}{dt}$ be the rate of change of current in the circuit.

Let $e$ be the E.M.F. set up.

Then $$e = L\frac{di}{dt}.$$

Let $i = I_0 \sin \omega t$.

$$\therefore \quad \frac{di}{dt} = \omega I_0 \cos \omega t \text{ (by the use of calculus).}$$

$$\frac{di}{dt} = \omega I_0 \sin (\omega t + 90°).$$

$$\therefore \quad e = \omega L I_0 \sin (\omega t + 90°).$$

Hence the current and voltage curves will be 90° out of phase, the current lagging by 90°.

The current wave is of amplitude $I_0$ and that of the voltage is $\omega L I_0$.

If a resistance R is incorporated in the inductive circuit, the value of the current is given by

$$i = \frac{e}{\sqrt{R^2 + (\omega L)^2}}.$$

(c) Alternating current applied to a circuit containing a pure capacity.

Suppose a quantity Q of electricity is given to a condenser of capacity $c$ and the potential to which it is raised thereby is $v$.

Then $$Q = cv.$$

If it is subjected to an alternating current, the current flowing will be equal to the rate of change of Q,

*i.e.*, if $$I_c = \text{current flowing}$$

$$-_{c} \qquad dt$$

$$= c\frac{dv}{dt}.$$

Suppose $v = V_0 \sin \omega t$

$$\frac{dv}{dt} = \omega V_0 \cos \omega t$$

$$= \omega V_0 \sin (\omega t + 90)$$

$$\therefore \qquad I = c\frac{dv}{dt} = \omega c V_0 \sin(\omega t + 90).$$

Hence the current leads the voltage by 90°.

The current has a maximum value $\omega c V_0$.

If a resistance is incorporated with the capacity, then

$$\text{voltage} \qquad = I\sqrt{R^2 + \frac{1}{(\omega c)^2}}.$$

### Methods of Producing High-frequency Currents

The three most important methods of producing high-frequency oscillating currents are :—

(1) The arc machine.
(2) The spark-gap machine.
(3) The valve machine.

In medicine only (2) and (3) are used, therefore the first will not be considered. The high-frequency oscillating current produced by these means may be either damped or undamped.

If there are no electrical losses in the circuit then all oscillations would be undamped, but, owing to losses due to resistance and capacity, damping occurs just as air resistance is the main cause of the amplitude of swing of a pendulum becoming less and less.

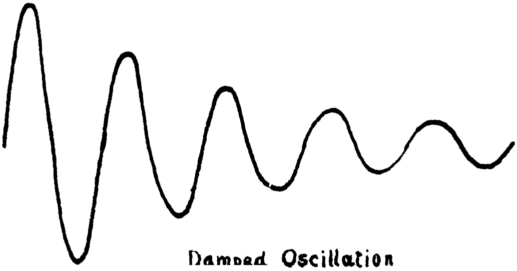


Fig. 15.

In spark-gap apparatus the oscillating circuit is made up of a condenser in series with an inductance and a spark gap.

Consider the following circuit consisting of a condenser of capacity C in series with an inductance L.

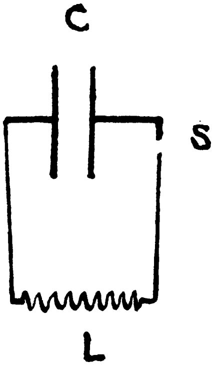


FIG. 16.

Now supposing an electric charge of Q coulombs be given to the condenser, then the voltage generated between the plates will be V equals Q/C volts and the electrical energy stored in the condenser will be $\frac{1}{2}$ $CV^2$ joules.

Now suppose a gap is introduced between the condenser and the inductance at S, and that it is possible to make the gap at S smaller or wider. Suppose it is a wide gap to start with. As the gap is made smaller and smaller the point is reached where the voltage between the plates of the condenser is sufficient to break down the insulation of the air in the gap and a spark is produced. This spark gap now becomes a resistance in the circuit and a high-frequency damped oscillating current is set up in the circuit This will go on until the energy left in the circuit is insufficient to maintain the ionisation of the spark gap. Let L be the inductance, C the capacity and R the resistance; the latter term includes the resistance of the spark gap when conducting and also the resistance of the leads, etc. Then the natural frequency of such a circuit is

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}.$$

As a rule the value of R is so small that the value of $\frac{R^2}{4L^2}$

is small compared with $\frac{1}{LC}$ and the formula becomes

$$f = \frac{1}{2\pi}\sqrt{LC}.$$

Now putting one charge on the condenser is not of much use, as it would only produce one train of waves. A method is used, therefore, to charge up the condenser to discharging voltage at regular intervals. For this purpose the secondary coil of a transformer is connected across the spark gap.

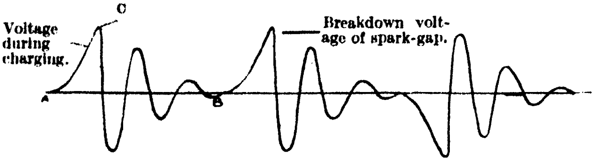


FIG. 17.

The voltage of this is usually very high, as otherwise (since energy $= \frac{CV^2}{2}$) to produce a reasonable quantity of energy the capacity would have to be so enormous, and this entails a big condenser. This in turn, since as explained above $f = \frac{1}{2\pi}\sqrt{LC}$, would mean that only fairly low-frequency oscillating currents could be obtained. Consider what happens to the voltage across the condenser during the process of charging and sparking.

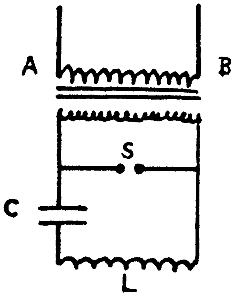


FIG. 18.

If the voltage corresponding to the point C is not the maximum voltage of the secondary of the transformer, then it may be that there is still time for the condenser to be charged again before the half cycle of the transformer voltage is over. In this case one may get another discharge, and so on. In the case drawn in Fig. 17 two discharges per half cycle are shown. The usual type of spark gap used is the so-called quenched spark. The design of this is such that the spark is put out very quickly. The theory of this will not be described here, but it does away, to a certain extent, with the heavy damping in the spark gap, and thus wasting the oscillatory current. The full diagram therefore of the spark gap method of producing high-frequency oscillating currents is shown in Fig. 18.

AB is the transformer, S the spark gap, C the condenser, L the inductance, and R the resistance. Since the frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L_2}}$$

it will be seen that by changing L and C the frequency may be changed (either increased or decreased).

## Thermionic Valve Method of producing High-frequency Oscillations

It has been pointed out before that a flow of electrons in one direction constitutes an electric current. When the temperature of a body is raised to incandescence it has been found that it becomes surrounded by a cloud of gas atoms and electrons. If this hot material is placed in a vacuum the number of electrons, N, emitted increases very rapidly with temperature, and can be found from the following relation :—

$N = ATe^{\lambda - b/T}$.
$A$ = a constant depending on the metal.
$T$ = Abs. temperature.
$\lambda$ = a constant (nearly unity).
$b$ = a constant (approx. 0·5).

No current is obtained merely from a hot body, however, as by the emission of electrons the material becomes positive and tends to attract electrons back. A state of equilibrium is set up. Suppose now in the evacuated tube with the glowing wire we place a plate of metal which is positively charged with regard to the wire (the filament). A stream of electrons will pass from the filament to the plate and the current will flow. If the plate is negatively charged with respect to the filament then no electrons flow from the filament to the plate. If an alternating voltage is applied between the glowing filament and the plates then the current will only flow during the half cycle when the plate is positively charged with respect to the filament. Hence a valve may be used as a rectifier. Such a valve is known as a diode valve. The introduction of a third electrode or grid increased the usefulness of the valve considerably. Now in a diode the current through the valve from filament to plate is controlled by the voltage between the filament and plate and by the temperature of the filament. Alteration of one or both of these factors alters the current through the valve. The usefulness of the grid lies in the fact that the current through the valve can be altered without altering the temperature of the filament or the potential on the plate. The grid is placed between the filament and the plate. When the grid is negative with respect to the filament it will tend to prevent the passage of electrons, and so decrease the current flowing from filament to plate. When the grid is positive then the plate current will increase, since more electrons can pass through the grid to the plate. The grid will, however, collect some electrons which will cause a current to flow in a circuit grid-filament. Whatever voltage is applied to the plate the current through the valve never exceeds a certain value. This is governed by the temperature at which the filament is maintained. From our point of view the important fact is that small changes

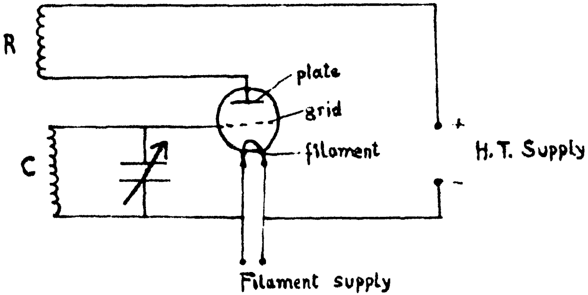


FIG. 19.

in the grid voltage produce much greater changes of current in the plate circuit than would be produced by the same changes of potential of the plate itself. In this way the current flowing in the plate circuit is controlled by the potential of the grid. To produce oscillations by the use of a valve a circuit, of which Fig. 19 is a simple example, is employed.

An oscillating circuit C, which includes a condenser and an inductance, is connected between the grid and the filament of a three-electrode valve, while the plate circuit is connected to a coil R. A high voltage is applied between the plate and the filament. When oscillations are set up in the circuit C by some disturbance, such as switching on the high-tension voltage, these produce variations of current in the coil R. If the coil has the correct dimensions and is correctly coupled to C, then the oscillating current induced in it will in its turn induce an oscillating current in the coil C again, thus tending to reinforce the oscillations taking place therein. If the coils are correctly coupled the energy transferred to the grid oscillating circuit becomes sufficient to make up for resistance losses in the grid circuit. Thus continuous undamped oscillations are set up. The electrical oscillations are analogous to mechanical oscillations (such as swinging pendulum) in so far as they show resonance effects. There is a story of the singer Caruso that he used to sing a musical note into a wineglass with such power that the glass was shattered. The note he sang was the natural frequency of the glass, and the resonant effect in it caused it to be shattered. Electrical resonance may be demonstrated by placing near the coil R (Fig. 20)

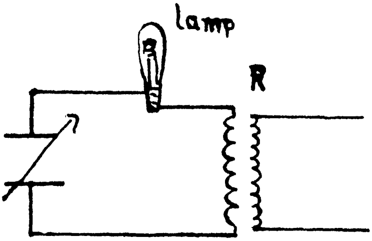


FIG. 20.

another coil in circuit with a variable condenser and a lamp.

When the natural frequency of this circuit (called a secondary circuit) is the same as that of the oscillations generated by the oscillator, then the electric lamp will glow at its maximum brightness. The adjustment to resonance is carried out by means of the variable condenser or by alteration of the inductance, or by both. This process is termed tuning the secondary circuit. Such circuits as this are said to be electro-magnetically or inductively coupled. Resonance effects may also be shown by two

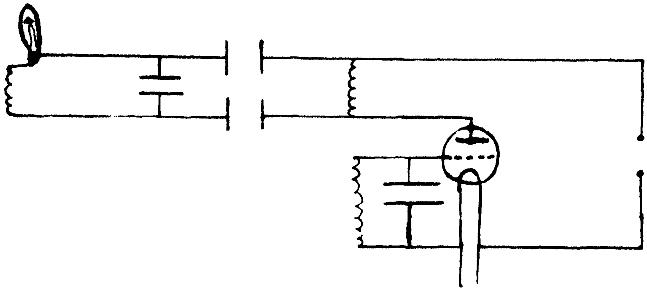


FIG. 21.

circuits coupled electro-statically by a condenser as shown in Fig. 21.

## ELECTRO-MAGNETIC WAVES

There is an important difference between the transfer of energy from an oscillating circuit through induction and by the radiation of energy as electro-magnetic waves. When two coupled circuits are close to one another the energy lost by the first, not taking into account internal losses due to resistance, etc., is almost the same as that acquired by the second. When the distance between the coupled circuits is made greater it is found that the energy appearing in the second circuit is less than that lost by the first. The oscillating circuit can also lose energy even if there is no secondary circuit near it. The energy is lost in the form of radiation at a rate proportional to the fourth power of the frequency, and to the square of the oscillating current. This radiation passes out into space with the velocity of light, and like light also it may be absorbed, reflected or transmitted. For all radiation the relation $V = n\lambda$ holds.

$V$ = velocity of radiation.
$n$ = frequency.
$\lambda$ = wavelength. In other words, $n\lambda$ = a constant.

$$\therefore \quad \lambda \propto \frac{1}{n}.$$

Thus the term frequency or the term wavelength may be used to define the type of radiation. This is commonly used, for instance, in broadcasting. The London Regional station being described as broadcasting on a wavelength of 342·1 metres, or with a frequency of 877 kilocycles.

## METHODS OF APPLICATION OF HIGH-FREQUENCY CURRENTS TO ELECTROLYTES AND BIOLOGICAL MATERIALS

(*a*) *By Conductive Currents.* As for example, by the use of the ordinary diathermy current (frequency usually of the order of 500,000 to 1,000,000 /sec.). Consider four solutions of electrolytes ABCD (Fig. 22) made up in agar so that they form solid blocks.

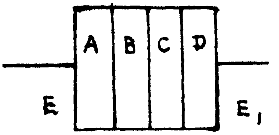


FIG. 22.

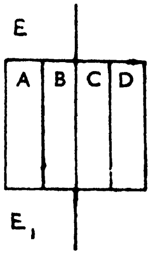


FIG. 23.

Suppose A is the strongest solution and D the weakest with the others intermediate in strength. In other words, D is less conductive than the other solutions, whilst A is the most conductive. Let E and $E_1$ be two electrodes connected to the source of high frequency, then a conductive current will flow from E to $E_1$ and *vice versâ.* Let the current at any instant be F. Then, since the electroytes are connected in series, the same current must be flowing in each solution. The rate of production of heat depends on the square of the current times the resistance. Thus the electrolyte with the highest resistance will have produced in it the maximum of heat. Suppose now the above electrolytes are connected in parallel as in Fig. 23. It is obvious now that the current flowing will not now be the same in all electrolytes, but will be at a maximum in electrolyte A, which has the least resistance.

Let V be the voltage at any instant between the electrodes E and $E_1$. Then the current in electrolyte A, $C_1$, $= \frac{V}{R_1}$ where $R_1$ is the resistance of electrolyte A. Current in electrolyte $D = C_4 = \frac{V}{R_4}$ where $R_4$ is the resistance of electrolyte D.

The rate of heat generation in A is $\frac{V^2}{R_1^2} . R_1 = \frac{V^2}{R}$.

The rate of heat generation in D is $\frac{V^2}{R_4^2} . R_4 = \frac{V^2}{R_4}$.

Which, since $R_4$ is greater than $R_1$, therefore heat generated in A is most, and in D the least. The reverse of what happens when the electrolytes are connected in series. In the case of the application of these currents to the body, there is nearly always a layer of fat of varying thickness in series with the other tissues. Since fat has a high resistance compared with vascular tissues, one would expect most heat to be generated in this tissue, and such is the case in practice. If two electrodes are applied to any part of the body, the current will spread itself throughout the whole body in such a way that in any particular path, the amount of current flowing will depend upon the conductivity of that path. Bone material also has a high resistance, but by its position in the body this must practically always be in parallel with more conductive tissues, then it in its turn will have little heat generated in it. The distinction must be drawn between amount of heat generated in a substance and its rise in temperature. Suppose we have two substances, one vascular tissue and the other fat, and we take the same quantities of each. If the same amount of heat is generated in both then the temperature of the fat will rise to a much higher degree than will that of the vascular tissue, since the specific heat (amount of heat required to raise 1 gram of the material 1° C.) of the former is much less than the latter.

(*b*) *By Displacement Currents.* The meaning of displacment current has already been given (p. 20). As pointed out, with increasing frequency, the amount of displacement current, produced in an object acting as the dielectric of a condenser, increases. To get sufficient displacement current to produce heating effects when there is no actual contact between the object treated and the electrodes, one has to use frequencies considerably higher than those used in the ordinary diathermy current. Hence the term short-wave and ultra short-wave treatment. The distinction of these treatments is that there is no conductive connection between the treated substance and the electrodes. These are usually separated by an air gap. The treated material as a rule forms part of a resonating circuit. Suppose we have the solutions of electrolytes ABCD as in Fig. 24 arranged in the following manner, E and $E_1$ being the treatment electrodes. Between E and $E_1$ is an electric field which changes with the high-frequency current flowing in the circuit to which E and $E_1$ are connected. In this case the maximum heat will not necessarily be generated in the solution of least conductivity, that is, the most dilute, as in the case of ordinary diathermy. The solution whose conductivity satisfies or most nearly satisfies the equation $p = \frac{\kappa}{f\epsilon}$ will be heated more than any other solution

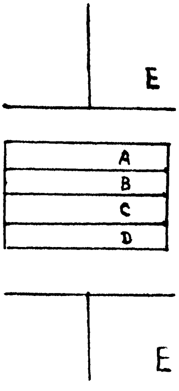


FIG. 24.

*where* $p$ *= specific resistance* $\left(\dfrac{1}{\text{sp. conductivity}}\right)$ in ohm cm.

$\epsilon$ *is the dielectric constant.*

$f$ is the frequency of the applied field.

If the conductivity of one of these solutions ABCD is not such as to satisfy this question, then the solution whose conductivity most nearly does so will be heated more than the others. Thus it is seen that for every wavelength there is a solution of a certain conductivity which will be heated more than other solutions. In general, solutions of any substances, if they have the same conductivity, are heated to the same degree. The higher the frequency of the applied field, the higher is the conductivity of the solution for maximum heating. In fact, the relation of these two factors is one of direct proportion. For a solution of given conductivity, however, subjected to varying frequencies there exists no frequency which will produce maximum heating ; the higher the frequency the greater the heating. To sum up :—

(*a*) With constant frequency and variable conductivity (variable concentrations) of an electrolyte, selective heating can occur.

(*b*) With constant conductivity and variable frequency there exists no frequency which produces maximum heating —as the frequency increases so does the heating effect.

(*c*) If a small part of the body is placed in the condenser field the effect of the high-frequency current is limited to the portion between and just surrounding the electrodes. The current does not spread throughout the whole body as in the case of conductive currents. Apart from this heating of the electrolytes in the high-frequency field, there is another way in which substances may be heated, namely, by *dielectric absorption* or *dielectric loss*, as it is often called. (This is mentioned on p. 25.) A large number of organic compounds, and more especially those containing OH group, show this phenomenon. Probably the great heating shown by fat in the high-frequency field is an example of this. At all wavelengths fat is heated to a far higher degree than any other tissue. Thus the heat production in the body by the high-frequency field is limited by the tolerance for heat of fat. It is easy to produce a fat burn in this way. Another way in which high-frequency currents can produce their *heating effects is by their action on dipoles, and some account of the theory of dipoles is not out of place here. The frequencies* required for this to be appreciable are usually considered to be higher than those used for treatment purposes. Suppose we have two substances, A and B, in the high-frequency field, and suppose A is fat and B vascular tissues in the position shown in Fig. 25. Let E and $E_1$ be electrodes, then with all frequencies fat will be heated to a much higher temperature. Since both these tissues have a higher dielectric constant than the surrounding medium (air) the lines of force will be closer together in the positions L as shown, since these tend to concentrate in media of higher dielectric constant. If now the tissues are connected in parallel as shown (Fig. 26), the lines of force will tend to segregate in the medium B which has a higher dielectric constant (80) than fat (4–16), thus one would tend to get less heating in the fat than in the previous case, and relatively more in the vascular tissue. That this is so may be shown by experiment.

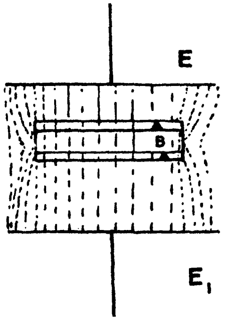


Fig. 25.

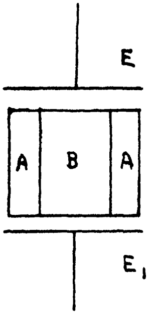


Fig. 26.

Let E and $E_1$ (Fig. 27) be the electrodes, A a layer of fat, B an agar block of normal saline. If now a high-frequency field is applied between E and $E_1$ the fat, A, may be melted without any appreciable rise in temperature in the agar block. If a hole is made in the middle of the agar block the layers of fat, A, being removed and a piece of fat inserted in this hole and covered with a small portion of the agar block, then when the field is switched on the fat does not rise to any appreciably higher temperature than that of the agar block itself. In the first case the lines of force must pass through the fat, in the second case they can avoid it to a certain extent because of the higher dielectric constant of the surrounding agar block, as shown in Fig. 28.

(c) *Heating by Currents set up by Electro-magnetic Induction.* As described (p. 27), it has been shown that a current flowing along a wire acts as a magnet. A magnetic field is set up. A coil of wire along which a current is flowing acts as a magnet. An alternating current flowing in a coil sets up a continuously changing magnetic field. Such a case is of a high-frequency current flowing in a coil. The magnetic field set up alternates with the same frequency as the exciting electric field. When a conductor is placed in a changing magnetic field a voltage is induced in the conductor, which of course then has currents generated in it. These induced currents flow in a random manner and are called *eddy* currents. These currents can produce heating, and it gives a method of heating conductors which are in an inaccessible position. These eddy currents will have the same frequency as that of the original high-frequency current flowing in the coil. If a non-homogeneous body, such as living tissue, is placed in a uniform alternating electro-

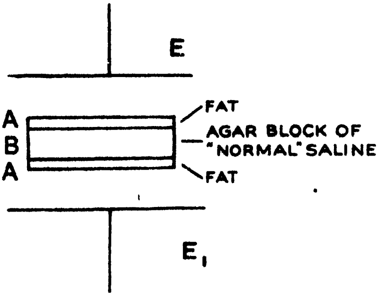


FIG. 27.

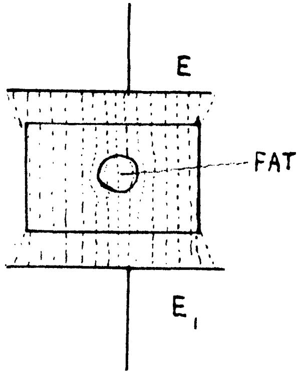


FIG. 28.

magnetic field, induced eddy currents will be set up in it. These will be most intense in the parts of the tissue having the highest conductivity. Thus one would expect most heat to be generated in these tissues. As a matter of fact, the heating power on living tissue is directly proportional to its conductivity. In the case of living tissues this is of course vascular tissue such as muscle, liver, etc. However, the problem is not so simple as this, since when applied to the human body the electro-magnetic field is very far from being uniform. The field will always be much more intense in the position nearest the wires carrying the current. The highly resistant tissues, fat and skin are the ones nearest the surface, and hence they will be subjected to the most intense field. This increase in field strength may be so great as to produce more heat in them than in the more conductive tissues subjected to a much weaker field. In the case of a non-magnetic substance (living tissue of course belongs to this class) placed in an electro-magnetic field no distortion of the lines of force takes place. Thus there is no likelihood, by this means, of producing a localised centre of high heating such as may be experienced when the condenser field method of heating is employed.

### Polar Molecules and their Importance in a High-frequency Electric Field

A positive and a negative charge of equal magnitude, at some distance apart, is called an electric dipole. In a large number of cases molecules act as dipoles. The molecule as a whole is electrically neutral. In cases where there are large numbers of positive and negative charges, one can find one positive charge and one negative charge which would be equivalent (find a sort of electrical centre of gravity, in other words). It often happens that these resultants with the positive and negative charges act at the same point; they neutralise one another, therefore. Such molecules are called non-polar. Good examples of the latter are to be found in benzene and hexane. When the resultants do not coincide, then the molecules are termed polar. Polarisation can sometimes be induced, by an electric field, in what are usually termed non-polar molecules. This is because the negatively charged electrons are attracted towards the positive pole and the positively charged nuclei

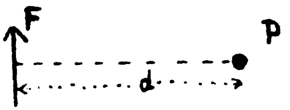


FIG. 29.

are attracted towards the negative pole. The moment of a force F, at a distance *d* from a point P, is F*d*.

Similarly, the electric moment of a charge Q at a point at a distance *d* from it is Q*d*. Now the electric moment of two charges, Q and $-$ Q, at a distance *a* apart is Q*a*.

This value Q*a* is called the *dipole moment*. When substances which are polar are subjected to an electric field,

FIG. 30.

the positive charge will be attracted towards the negative pole and the negative towards the positive pole. For example, a dipole $\overset{+}{Q}\text{——}\overset{-}{Q}$ when placed in an electric field will tend to go into the position shown in Fig. 31. The molecules will be set in the electric field so that the axis joining the resultant of the positive and negative charges

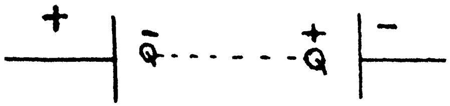
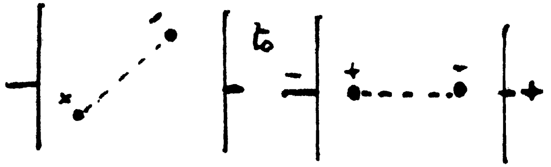


FIG. 31.

is parallel to the electric field. This motion, however, is opposed by the purely thermal agitation of the molecules, which are themselves in a state of violent agitation. This orientation, due to an electric field, usually makes itself known by a small displacement such as that represented in Fig. 32 (from *a* to *b*).

Suppose now that an alternating field is applied to a system of polar molecules: each alternation is a change in polarity, thus each molecule gets alternate twists in opposite directions. This sets them oscillating about an axis in a similar manner to the way a compass needle swings. For a dilute solution polar molecules in a non-polar solvent the power factor passes through a maximum given by $f = \frac{kT}{[illegible]}$ where *k* is a constant called Boltzman's constant. T is the absolute temperature, *a* is the radius of the equivalent sphere, representing the dipole molecule or group, and $\eta$ is the viscosity opposing the orientation of the molecules, thus for molecules of a certain size one can calculate the frequency at which maximum dielectric loss will occur.



(*a*) (*b*)

FIG. 32.

## CHAPTER IV

# HIGH-FREQUENCY CURRENTS AND THE ELECTROTECHNICAL PRINCIPLES UNDERLYING THEIR PRODUCTION

### Meaning of High Frequency

WHEN the qualification " high frequency " is applied to an electric current it signifies that the current is one which alternates (oscillates) at an exceedingly high rate. The power of an alternating (oscillatory) current to make the excitable tissues, viz., muscle and nerve, exhibit their customary physiological responses depends, not only on the *intensity* which the current attains, but also on the *frequency* with which it alternates (oscillates).[1] A sinusoidal alternating current strong enough to cause contraction of muscle would no longer be able to do so if its rate of alternation were raised from its usual value (50 cycles per second) to 10,000 per second. If, now, the current were increased in strength it would again be able to cause contraction, but it would again lose its power to do so if its frequency were made higher than 10,000 cycles per second. If its strength were increased to two or three *amperes*—values which are often reached in diathermotherapy—the frequency of its oscillation would have to be raised at least to 400,000 cycles per second in order to prevent stimulation of muscles and nerves.

Speaking medically, the frequency of oscillation of a current may be called *high* when the current is no longer able to stimulate the excitable tissues. Before the frequency is expressed in figures the strength of the current must be known. The stronger the current the higher must be the frequency. It is in treatment by *diathermy* that the strongest currents are employed. The frequency of their oscillation should not be less than about 400,000 cycles per second. Currents oscillating with lower frequency are not utilised in the other forms of electrothermic treatment. From the point of view of electrothermic treatment the frequency of oscillation may be called "high" when it is *not lower* than about 400,000 cycles per second.

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[1] Alternating currents are also called oscillatory currents. When speaking of high-frequency currents it is customary to use the words *oscillate* and *oscillatory*, rather than *alternate* and *alternating*.

### HOW OSCILLATION WITH HIGH FREQUENCY IS OBTAINED

If a condenser, *e.g.*, a Leyden jar, is charged and then allowed to discharge, a current of *momentary* duration will accompany the discharge. If the circuit along which the discharge takes place has a *high* resistance (such as that of the human body) the current will be *unidirectional*. If, however, the circuit has a *low* resistance (like that of metal) the current will be oscillatory.

The frequency of the oscillation is determined by two factors; the first is *capacity* of the condenser, and the second is the amount of *self-inductance* that takes place in the circuit. The smaller the capacity, the higher the frequency, and *vice versâ*. If the circuit is a straight or slightly curved wire, thereby allowing only a minute amount of self-inductance to take place, the frequency of the oscillation will be much higher than would be the case if the wire were bent in the form of a coil so as to allow more self-inductance to take place. By selecting a suitable condenser and inductance coil the frequency of the oscillation can be made the value desired.

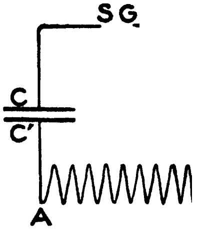

Fig. 33.—Plan of Circuit containing Condenser (CC′), Inductance (AB), and Spark-gap (SG).

In the plan shown in Fig. 33, C and C′ represent the two plates of a condenser. It is placed in a circuit containing an inductance coil AB. There is a gap in the circuit at SG. When the condenser is charged and the difference of potential between the plates is high enough a spark will appear at the gap and the condenser will discharge. During the moment while the spark is present at the gap a current will oscillate in the circuit.

The gap SG is known as the *spark-gap* and the inductance coil AB is called the *oscillator*. The circuit containing the condenser, oscillator and spark-gap is called the *oscillating circuit.*

### Voltage. Frequency. Damped Oscillation

An oscillatory current accompanying the discharge of a condenser is graphically represented in Fig. 15, p. 32.

When a condenser discharges in this manner the voltage and amperage attain less high maximum values during one oscillation than during the preceding one. For this reason the oscillation is described as *damped*. Oscillation of this kind is represented in Fig. 15.

The *frequency* of the oscillation is the number of complete oscillations per second.

The maximum voltage attained is determined by the width of the spark gap in the circuit.

### Sustained and Unsustained Oscillation

The time occupied by the group of oscillations accompanying the discharge of a condenser is extremely brief. But if the condenser is re-charged after each discharge one group of oscillations will be followed by another. In this way oscillation can be made to last over any length of time. If there is no interval between the end of one group and the beginning of the next the oscillation in the circuit will go on without interruption. The current is then said to be one of *sustained oscillation.* On the other hand, if there is an interval between the end of one group and the beginning of the next the oscillation in the circuit will be *unsustained.* The current then is said to be one of *unsustained oscillation.* In both cases the oscillation accompanying each discharge will be damped. Sustained oscillation is graphically represented in Fig. 17, p. 34.

### The Original Type of High-frequency Current Generator

In the early days of empirical " high-frequency treatment " Leyden jars were used as condensers. They were charged by means of a long-spark induction coil. The primary winding of the coil was connected to a source of *direct* current and a mechanical interrupter was used. The

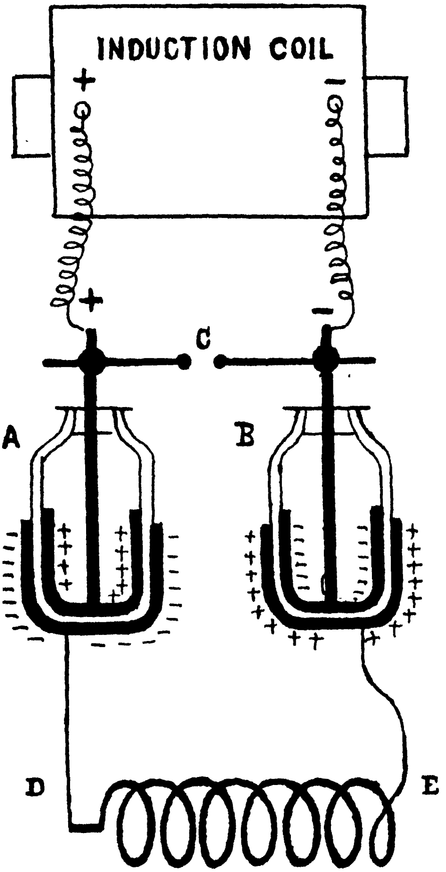

FIG. 34.—Plan showing connections of Leyden jars (A and B), solenoid (DE) and spark-gap (C) in the original type of apparatus (d'Arsonval transformer).

ends of the secondary winding were connected to the inner coats of the jars, as indicated in the plan (Fig. 34). The outer coats were connected by a coil of thick copper wire wound in a cylindrical form. This was the oscillator. It was sometimes called the *solenoid*. The spark-gap consisted of a pair of metal rods which could be moved apart from each other so as to provide a space of 1 to 3 in. between their free ends. The patient's electrodes were connected to the ends of the oscillator.

When the machine was in operation there was a continuous torrent of sparks between the ends of the metal rods. The noise was so loud that the metal rods were enclosed in a glass chamber so as to render it less audible. The jars were charged once at each interruption of the current in the primary winding of the coil. After each charge they discharged across the spark-gap and along the oscillator.

It was calculated that the group of oscillations accompanying each discharge lasted only $\frac{1}{50000}$ sec. If the jars were charged 100 times per second—that being the frequency of interruption of the current in the primary winding of the coil—it follows that the interval after each group of oscillations was almost $\frac{1}{100}$ sec. In other words, it was almost 500 times longer than the time occupied by the preceding group of oscillations. Consequently the patient was under the influence of the high-frequency current for only $\frac{1}{500}$ of the time during which the machine was working. Hence little heat was produced in the body during a *séance* of treatment.

## Present-day Generators

The high-frequency current generators employed at the present day are of two main types. Machines of the first type are constructed on the same general plan as that already described, but the component parts are modified and certain additions are made. They are known as *spark-gap generators*. Machines of the second type are known as *valve generators*. They contain a triode valve in place of a spark-gap.

### MODERN SPARK-GAP GENERATORS

Plate condensers are used in place of Leyden jars. They have a larger electrical capacity, and the duration of their oscillatory discharge is less brief. They are charged from the secondary winding of a static transformer, the primary winding being supplied with current from the A.C. main. This obviates the necessity for a mechanical interrupter. The plate condensers discharge across the space between a pair of metal discs. The distance between them is very much smaller than that between the metal rods of the original machine ; it may be no more than $\frac{1}{25}$ in. (1 mm.). In all machines except the smallest there are two, three or four pairs of discs grouped in series. The object of providing more than one space is to prevent overheating of the metal discs. The total width of the spaces is not more than about 1 mm. Consequently the voltage to which the condensers are charged is very much lower than was the case with the original machine. In the latter it was unnecessarily high. The oscillator is usually a flat coil like a large clock-spring. The patient's electrodes could be connected to the ends of the oscillator, but in most machines they are connected to the ends of a separate coil resembling the oscillator and known as the *resonator*. The oscillator and resonator are placed in parallel planes. The former is sometimes called the *primary inductance* coil and the latter the *secondary inductance* coil. In the circuit containing the resonator another condenser is placed, also an ammeter.

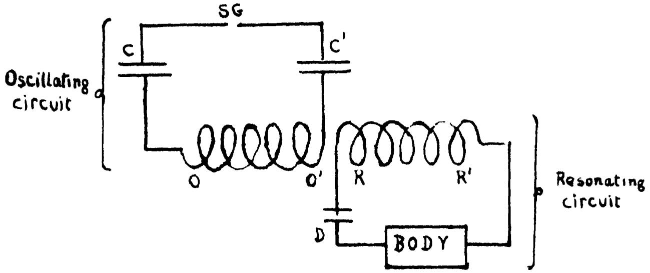

FIG. 35.—Plan of an Oscillating Circuit with a Resonating Circuit adjacent to it. C and C′, condensers in oscillating circuit ; OO′, oscillator ; SG, spark-gap ; D, condenser in resonating circuit ; RR′, resonator.

The circuit containing the oscillator is known as the *oscillating circuit*, and that containing the resonator is known as the *resonating circuit*. In the plan shown in Fig. 35, C and C′ represent the condensers in the oscillating circuit, OO′ the oscillator, and the space SG the spark-gap. In the resonating circuit RR′ indicates the resonator, and D represents a small condenser. The patient's body is represented in this circuit.

The condenser is charged, as already stated, by means of a static transformer. The primary coil of the transformer is connected to the A.C. main. The ends of the secondary coil are connected to the oscillating circuit as shown in Fig. 36. In this Fig. PP′ represents the primary, and SS′

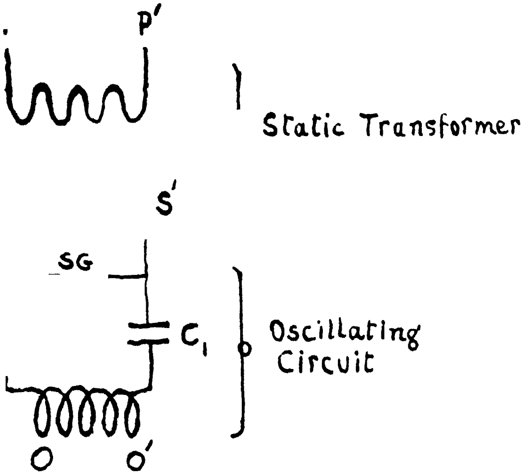

FIG. 36.—Plan showing Static Transformer (primary coil PP′, secondary coil SS′); and Oscillating Circuit (condensers C and $C_1$, oscillator OO′, and spark-gap SG). The connections of the secondary coil to the oscillating circuit are shown.

the secondary coil of the transformer. The oscillating circuit is like that shown in Fig. 35.

### Events in the Different Circuits

The following are the events that occur in the different coils and circuits. These coils and circuits are schematically represented in Fig. 37, A. They are the primary coil of the transformer (1), the secondary coil (2), the oscillatory circuit (3), and the resonating circuit (4). The oscillator and resonator are represented as flat coils.

(1) Events in the *primary* coil. In this part of the circuit is the alternating current from the main. The E.M.F. increases from zero to maximum (*a* to *b*) and then diminishes from maximum to zero (*b* to *c*); the E.M.F.

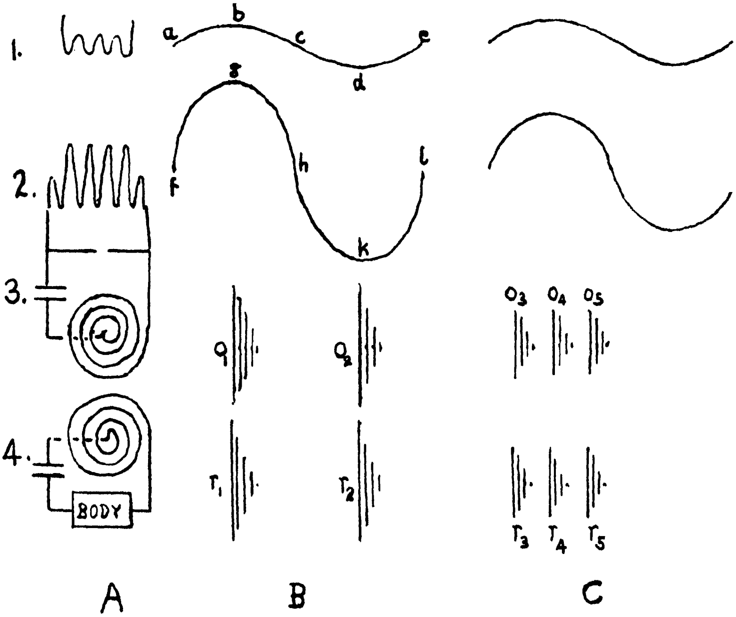

FIG. 37.—Diagram to explain Events in a High-frequency Current Generator. A, The Coils and Circuits; 1 and 2 are the Primary and Secondary Coils of the Transformer; 3 is the Oscillating, and 4 the Resonating Circuit. B, *abcde* represents one complete cycle in the Primary Coil of the Transformer; *fghkl* represents one complete cycle in the Secondary Coil; $o_1$ and $o_2$ represent two groups of high-frequency oscillations in the Oscillating Circuit; and $r_1$ and $r_2$ represent two groups in the Resonating Circuit. C, $o_3$, $o_4$ and $o_5$ represent *three* groups of oscillations in the Oscillating Circuit, and $r_3$, $r_4$ and $r_5$ represent *three* groups in the Resonating Circuit during a *half-cycle* in the Primary and Secondary Coils.

now reverses and again increases from zero to maximum (*c* to *d*) and then diminishes from maximum to zero (*d* to *e*). One complete cycle or period is represented by *abcde*.

(2) Events in the *secondary* coil of the transformer. In this there is an induced E.M.F. which increases and

diminishes and then reverses in the same manner as in the primary coil, but attains a higher maximum One complete period or cycle is represented by *fghkl*.

(3) Events in the *oscillating* circuit. When the E.M.F. is rising the condenser in the oscillating circuit is charged to an increasing height. When the E.M.F. has reached its maximum (as indicated at $g$) the condenser discharges across the spark gap and a current oscillates with high frequency in the circuit. The train of oscillations is represented by $o_1$. The oscillation is quickly reduced to zero (in other words, it is strongly damped) and no more oscillation occurs until the induced E.M.F. again attains its maximum value (at $k$), when the condenser again discharges. Accompanying this discharge is a second train of oscillations ($o_2$).

(4) Events in the *resonating* circuit. Each train of oscillations in the circuit just considered induces another train in the resonating circuit ($r_1$ and $r_2$).

Two trains of oscillations occur, therefore, during each period (cycle) of the alternating current in the primary coil of the transformer. Consequently, if this current has a periodicity of 50 (*i.e.*, 50 complete periods per second), there will be 100 trains of oscillations per second in the resonating and oscillating circuits.

It was assumed above that the spark gap was at its maximum width, thereby preventing the condenser from discharging across it until the E.M.F. reached its maximum value. Suppose now that the gap is made narrower. The condenser will be able to discharge across it before the E.M.F. reaches the maximum values indicated at $g$ and $k$. There will be time, therefore, for the condenser again to charge and discharge before the current in the primary coil of the transformer has completed a half-period (*abc*). Assume that the spark gap is narrow enough to enable the condenser to charge and discharge three times during each half-period. The result will be three groups of oscillations, instead of one, in the oscillating circuit, and the same number in the resonating circuit. They are represented by

$o_3$, $o_4$ and $o_5$, and $r_3$, $r_4$ and $r_5$ (Fig. 37, C). During each complete period there will be six groups; and as the duration of each complete period is $\frac{1}{50}$ sec. there will be 300 groups of oscillations each second instead of 100.

It will be noticed that the interval between the groups of oscillations represented at C (Fig. 37) are much shorter than those indicated at B. But the voltage during the oscillation reaches a less high value when the spark gap is narrowed for the purpose of enabling more groups of oscillations to occur per unit of time. The narrower the spark gap the more frequently will the condenser be charged and discharged and the greater will be the number of groups of oscillations until eventually there will be no intervals between successive groups. In other words, the oscillation will be *sustained.* On the other hand, the more frequent the charging and discharging the lower will be the maximum voltage during the oscillation, and it may become too low to produce a current of the required amperage in that part of the body where it is used.

## Voltage and Amperage in the Resonating Circuit

It has already been stated that the maximum voltage reached in the oscillating circuit depends on the width of the spark gap. The maximum voltage that is reached in the *resonating* circuit depends, in the first place, on the number of turns in the resonator as compared with those in the oscillator. If the resonator contained many more turns than the oscillator a higher voltage could be produced in the former than in the latter. But the increase in the height of the voltage is obtained at the expense of the amperage. By employing a resonator containing a great many more turns than the oscillator the voltage can be increased to the heights necessary to produce an effluve or the sparks used for treatment by electrodesiccation. In the form of an effluve, or of sparks, the *current,* however, has a negligibly low value. The converse is the case in regard to diathermy and the arc used for cutting. Currents of relatively high amperage are needed, and the comparatively low voltages that produce them are obtained by employing resonators containing a small number of turns.

## Production of Current in Resonating Circuit

The process whereby the current in the oscillator induces another in the resonator has already been said to be that of induction. The current is induced not only by the changing magnetic field around the oscillator but also by the electro-magnetic waves that proceed from the oscillator. The latter process, and the reason why the oscillator and resonator are known by these names, will more readily be understood if an analogous phenomenon is described. Two tuning forks are placed in close vicinity to each other. The first is made to vibrate. The sound waves that proceed from it will make the second fork vibrate, or *resonate*, providing the second fork is correctly placed in relation to the first, and the natural rate of vibration of the second fork is the same as that of the first.

The oscillating circuit corresponds to the first fork. Electro-magnetic (Hertzian) waves are emitted from it. The resonating circuit corresponds to the second fork. The Hertzian waves will cause a current to appear in it (that is, it will make it *resonate*) provided two requirements are satisfied. In the first place the *situation* of the resonator must bear a proper relationship to that of the oscillator. In the second place the capacity of the resonating circuit, and the amount of self-inductance that it allows, must have a proper relationship to the same factors in the oscillating circuit. It will be remembered that these factors decide the frequency of the oscillation in a circuit. If the capacity and self-inductance in the resonating circuit determine a frequency that is widely different from that in the oscillating circuit there will be no oscillation in the resonating circuit.

## Coupling

If the position of the resonator in relation to the oscillator is such that the current in the latter causes another current in the former, *i.e.*, if *resonance* occurs, the two coils are said to be *coupled*. They are said to be *uncoupled* when, by reason of incorrect relative position, no resonance occurs. Coupling can be *close* or *distant*. The closer the coupling the less the loss of electric energy in the transfer from one circuit to the other.

When the oscillator and resonator have the form of cylindrical spirals (as is the case in some generators) they are *coupled* when their long axes are on the same straight line. The greater the distance to which the resonator is moved from the oscillator, *i.e.*, the less closely they are coupled, the weaker will be the current in the resonating circuit. Conversely, the nearer the resonator is to the oscillator the stronger will be the current. If the resonator has a smaller diameter than the oscillator it can be placed actually within the oscillator. In this position the current in the resonating circuit will attain its maximum value, the coupling being the closest.

When the oscillator and resonator have the form of *flat* spirals (which is the case in most diathermic machines) the current in the resonating circuit will attain its maximum value when the two coils are in parallel planes, opposite one another and close together. The farther they are apart the weaker will be the current in the resonator. If they are parallel and close together but not precisely opposite each other the current in the resonator will be less than it would be if one coil were exactly over the other. By moving one coil laterally from under the other the current in the resonator will fall in value, and when one coil does not overlap the other at all there will be no current in the resonator. In this position the oscillator and resonator are *uncoupled*.

## Tight and Loose Coupling

It is not essential that the resonator and oscillator should be separate and distinct coils. Resonance can occur if the resonator is continuous with the oscillator. In the plan shown in Fig. 38 a cylindrical coil (ORS) is represented ; the turns at one end constitute the oscillator (OR) and the remaining turns the resonator (RS).

When the resonator and oscillator together constitute a single coil the coupling is said to be *tight*. When they are separate and distinct coils the coupling is said to be *loose*.

When the coupling is tight it is easy to adjust the voltage in the resonator in relation to that in the oscillator by moving the point of connection of the cable X (Fig. 38) with the coil. If it is moved towards O the number of turns in the resonator will be increased and the voltage at S will be raised. If it is moved towards S the number of turns in the resonator will be decreased and the voltage at S will be lowered. In this way the strength of current in the resonating circuit can be adjusted. In diathermic machines tight coupling is the exception rather than the rule—at any rate in those of English make. But in generators constructed for procuring an effluve (p. 308) the oscillator usually is tightly coupled to the resonator. The last-mentioned coil contains a great many more turns than the oscillator in order that the requisite high voltage may be obtained.

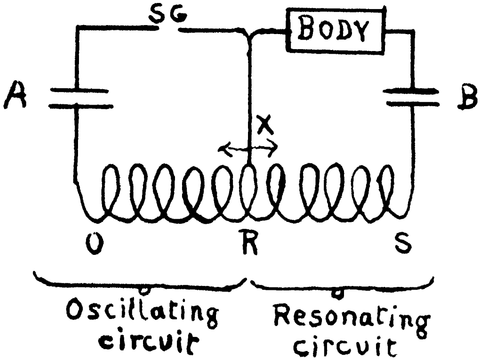

FIG. 38.—Plan of Oscillating and Resonating Circuits with the Oscillator OR *tightly* coupled to the Resonator RS. A and B, Condensers; SG, Spark-gap; X, Movable Connection.

## Relationship required between the Capacity and Inductance in the Oscillating and Resonating Circuits

After the oscillator and resonator are coupled, either tightly or loosely, another requirement must be fulfilled before the current in the oscillating circuit can cause another to appear in the resonating circuit, that is, before resonance can occur. The resonating circuit contains a condenser (B, Fig. 38) and the body. The condenser and the body and the connecting wires make up a total capacity K′. The amount of self-inductance that takes place in this circuit is determined mainly by the resonator (RS, Fig. 38). Let L′ denote the amount of self-inductance that takes place in the resonating circuit. In the case of the oscillating circuit let K denote the capacity and L the amount of self-inductance. If KL = K′L′ the electrical energy conveyed to the resonating circuit will be the maximum possible. In other words, the maximum resonance will take place. The greater the difference between KL and K′L′ the less the resonance, and when the difference is great enough no resonance will occur, and there will be no current in the resonating circuit.

Since K′L′ must be equal to KL if maximum resonance is to take place it is obvious that any increase of L′ must be accompanied by a corresponding *diminution* of K′. In other words, an increase of the amount of self-inductance in the resonating circuit makes it necessary to *diminish* the capacity of the condenser in the same circuit, and *vice versâ*. Thus when the resonator contains very many more turns than the oscillator—as it does in the apparatus for producing an effluve—its inductance is so large that it is unnecessary to place a condenser in the circuit; the capacity of the coil and that of the body is sufficient to enable maximum resonance to take place.

### USE OF A TRIODE VALVE IN THE PRODUCTION OF HIGH-FREQUENCY CURRENTS

All forms of electrothermic treatment can be practised with generators constructed on the principle already described. They are known as “ spark-gap machines ” in order to distinguish them from generators of another type which contain a triode valve. In these there is no spark gap. They are known as “ valve machines.” Some authorities consider them more efficient than spark-gap machines in one of the surgical forms of electrothermic treatment, viz., electrosection (p. 8), while in the practice of “short-wave" therapy (p. 6) a valve machine is more often employed than a spark-gap machine.

In Fig. 39, A, is represented an oscillating circuit containing a condenser, an inductance and a spark gap. The source from which the electrical energy is derived for the purpose of charging the condenser, after each discharge, is the secondary coil of a static transformer. This arrangement is no different from that already described. At B is represented another oscillating circuit which, however, contains no spark gap. The source from which the electrical energy is derived is not connected to the oscillating circuit in the same way as that indicated at A. It is in a separate circuit of its own. In this circuit is an inductance which is coupled to the inductance in the condenser circuit.

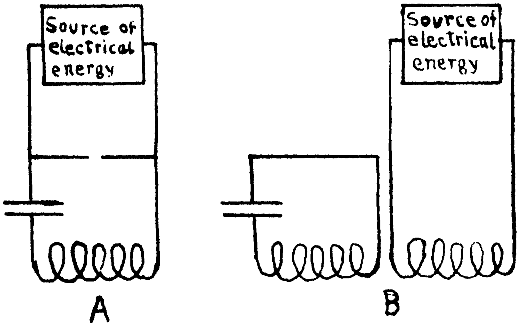

FIG. 39.

Suppose, now, that the condenser received a charge. A current will oscillate for a moment in the condenser, but the oscillation will quickly die away. It could be prevented from dying away, however, if another current were made to flow, at the appropriate moments, in the condenser circuit. This additional current is derived, by the process of induction, from the coil which is coupled to the inductance in the condenser circuit. The coil is in the circuit that contains the source from which the electrical energy is derived (see Fig. 39, B).

Now it is obvious that the current must be induced into the inductance in the condenser circuit precisely at the correct moments. It is *unidirectional*, whereas that in the condenser circuit is *alternating*. If it were induced at the wrong moments it would oppose the current in the condenser circuit and the condenser would not be charged. But as the current is induced exactly at the correct moments the condenser is maintained in a charged condition. Consequently a current continues to oscillate in the condenser circuit.

It is the function of the valve to enable the current in the circuit containing the source of electrical energy to flow at the correct moments. The current in this circuit is unidirectional and the valve makes it pass intermittently, interrupting it with the same frequency as that of the oscillation of the current in the condenser circuit.

The construction and working of a triode valve, and its position in the circuit, are described in the chapter on *Physical Principles* (p. 35 *et seq.*).

In order to obtain a current of sustained and undamped oscillation it is necessary that the source from which the electrical energy is derived should be one of *high* E.M.F. that does not vary. The voltage of the D.C. mains is not nearly high enough. A static transformer must be used and its primary coil connected to the A.C. main. The high E.M.F. in the secondary coil is rendered non-alternating by means of a rectifier, and relatively constant by means of condensers and choke coils.

It is more usual, however, to omit the rectifier, condensers and choke coils. In this case the E.M.F. in the secondary coil is an alternating one. As it is only the E.M.F. in one and the same direction that can be utilised, it follows that the high-frequency current yielded by the machine is not one of sustained oscillation. The oscillations occur in groups corresponding to each semi-phase of the main alternating current.

### GENERATORS FOR PROVIDING CURRENTS FOR DIFFERENT ELECTROTHERMIC METHODS

The currents employed in the various electrothermic methods exhibit different ranges of frequency, voltage and amperage. Some information on this subject was given in the introductory chapter. Having described the principles and methods of obtaining currents that oscillate with high frequency it will not be out of place to add a few words on the ways in which the general design of the generator is modified in order to enable it to yield the current most suitable for each form of treatment. The actual machines will be described in later chapters.

All the machines employed in each of the different forms of treatment contain a static transformer. The height to which the voltage is raised in the secondary coil is less important than the *size* of the transformer. In forms of treatment such as diathermotherapy, short-wave treatment and inductothermic treatment, in which currents of high amperage are administered for long periods, it is essential for the transformer to be large in size so as to enable it to receive from the source of supply a large amount of electrical energy without being overheated.

On the other hand, in the surgical forms of electrothermic treatment, a smaller amount of electrical energy is needed. Consequently the transformer, the other parts of the machine and the size of the generator need not be large.

The electrical energy received by the transformer is given out in the form of a high-frequency current and the machine is constructed so as to yield either a high *amperage* (in which case the voltage will be low), or a high *voltage* (in which case the amperage will be low). The number of turns in the resonator in relation to those in the oscillator (*i.e.*, the factors that help to decide the amount of inductance that takes place in each coil) determine the voltage and amperage yielded by the machine.

Thus, for diathermic treatment, in which a high amperage is required, the voltage is kept at a relatively low value. This is secured by using a resonator containing not many more turns than the oscillator. For surgical treatment by means of sparks (which may be as long as ½ in., and sometimes much longer) a high voltage is required. *It is obtained by using a resonator that contains many more turns than the oscillator.* *For* non-surgical treatment by means of long thin sparks, or an effluve, the very high voltage needed is obtained by using a separate resonator containing a great many more turns than the oscillator.

To obtain an arc for the purpose of cutting, the voltage is kept at a value lower than that used for the production of diathermy. This can be effected by employing a resonator containing fewer turns than the oscillator, also by narrowing the air spaces in the spark gap.

The frequencies of the currents employed in the different electrothermic methods of treatment were mentioned in the introductory chapter. The frequencies best suited for each method are obtained by fitting condensers that have the requisite capacities, and oscillators that allow the right amount of inductance. For the production of diathermy the frequency ranges, as already stated, between 500,000 and 2,000,000 cycles per second. The much higher frequencies employed in inductothermy (12,000,000 cycles per second) and in short-wave treatment (ranging between 10,000,000 and 100,000,000 cycles per second) are obtained by fitting oscillators containing a very few turns that are widely spaced, thereby allowing only a minute amount of inductance.

The only form of electrothermic treatment in which it is essential to use currents of *sustained* oscillation is electrosection, *i.e.*, the form in which an electric arc is employed for cutting tissue. When the machine is one of the spark-gap type the use of a very narrow gap, as explained on p. 57, will provide a current of sustained oscillation. When valve machines are used the current which they supply will not be one of sustained oscillation unless the voltage in the secondary coil of the transformer is rectified (that is, rendered unidirectional) and made as nearly constant as possible.

## Number of Machines required for Practice of Electrothermic Treatment

*If it is desired to practise every form of electrothermic treatment, medical as well as surgical, viz., medical diathermic treatment, effluvation, short-wave treatment, inductothermic treatment, electrocoagulation, electrodesiccation* and electrosection, it is not necessary to have seven generators. The generator which has the most uses is the medical diathermic machine. It can be employed as well for treatment by electrocoagulation and—with the help of some accessory apparatus—electrodesiccation and effluvation. Short-wave treatment needs a generator specially constructed for the purpose. The same is true of inductothermic treatment. *The short-wave machine is not suitable for other forms of treatment. The inductotherm machine can be fitted with extra parts which enable it to provide an arc suitable for* electrosection. Electrosection, however, is the work of the surgical specialist, rather than the specialist in electrotherapeutics, and the same is true of electrocoagulation and electrodesiccation when they are practised in *certain regions*, such as the bladder and the upper air passages. Surgeons do not deal with medical electrothermic treatment. These facts will ultimately decide the types of apparatus made and used in the future.

# PART II

# MEDICAL ELECTROTHERMIC METHODS AND THEIR USES

SECTION I. DIATHERMY AND DIATHERMOTHERAPY.

,, II. EFFLUVATION AND ÉTINCELLAGE.

,, III. SHORT-WAVE THERAPY.

,, IV. INDUCTOTHERMY.

# SECTION I

# DIATHERMY AND DIATHERMOTHERAPY

## CHAPTER V

## MEANING OF TERMS

THE literal meaning of the word *diathermy* is heat distributed through an object and not confined to one part of it.[1] Being an electromedical term it is used in connection with the heating of one object in particular, viz., the body, and with the production of the heat by an electrical method. The method is one in which the body, or a region of it, is included between a pair of electrodes and placed on the path of a high-frequency current.[2] In the Introduction it was pointed out that currents of frequencies ranging between 500,000 and 100,000,000 cycles per second are employed for the purpose of generating heat in the body. The word *diathermy* will be reserved, however, for the heat generated by currents of the lower range of frequencies, viz., between 500,000 and 2,000,000 cycles per second.

The prefix *dia* implies that the heat is generated *through*,

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[1] The word *diathermy* is derived from the Greek δια (meaning *through*) and θερμος (meaning *hot*). Since the word is a substantive, and *hot* an adjective, *diathermy* is bastard English. French and German writers use the word *diathermie*, and Italian writers call it *diatermico*.

[2] There are ways, other than electrical, of heating the body and procuring a rise of temperature of the deep as well as the superficial parts. If the entire area of the skin, or the greater part of it, is exposed to hot air, hot water or other hot objects, or to radiant heat, the superficial structures of the body will rise in temperature and some of the heat will be conveyed by the circulation to the body as a whole. Literally speaking, this is diathermy. But the expression diathermy is not used in association with the heating of the body in this way, although a "diathermic distribution" is obtained. "Ready-made" heat derived from external sources and applied *locally* cannot reach the parts at more than a slight depth below the site of application because it is carried away by the blood circulating in the superficial parts and distributed throughout the body as a whole.

*i.e.*, *throughout*, the region on the path of the current. The use of the word *diathermy* in its literal sense conveys the impression that any region of the body and all the organs and tissues therein can be heated through-and-through by the current. This, the original view, will be shown in Chapter VII. to be not entirely correct. Nevertheless, in view of the present uncertainty as to the distribution of temperature brought about by currents of different frequency, the word *diathermy* will be retained, but it will be used without implying that there is necessarily a rise of temperature in all the organs on the path of the current.

When it was realised that heat could be generated in the body by means of high-frequency currents of sufficient intensity, the terms " transthermy " and " thermopenetration " were used for a time. These hybrid and inelegant expressions (the latter being, in addition, inaccurate) were afterwards replaced by the word *diathermy*, which now is universally used.

Diathermy is said to be *medical* when the degree of the heat is insufficient to harm the tissues or impair their vitality. The qualification *medical* serves to distinguish it from diathermy of the *surgical* kind—that in which the heat is intentionally raised to a degree high enough to kill the tissue under treatment. Treatment by diathermy may be called *diathermotherapy*, or, if preferred, *diathermic treatment*.[1]

A current which oscillates with a frequency of which the lower limit is 500,000 cycles and the upper limit about 2,000,000 cycles per second will be called a *diathermic* current, provided, of course, that it attains an intensity sufficient to heat the tissues. Although currents oscillating with far higher frequency have as much (or as little) right to be termed *diathermic* when they generate heat in the body, the qualification *diathermic* will be applied to currents of which the range of frequency is that just stated.[1] This reservation will prevent confusion between the currents that form the topic of the present Section, and those of far higher frequency which are considered in subsequent Sections.

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[1] The word diathermy, as already stated, is a substantive. It is commonly used also as an *adjective*, as, for example, in the expressions *diathermy treatment*, *diathermy current*, etc. It would be better to make the adjective *diathermic* (cf. *faradic* and *galvanic*). The French use *diathermique* and the Germans *diathermisch* as the adjective.

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[1] Mention has already been made of the uncertainty as to the distribution of temperature in the parts on the path of currents of frequencies ranging between 500,000 and 2,000,000 cycles per second. There is equal uncertainty in regard to currents of much higher frequency.

# CHAPTER VI

## DIATHERMIC CURRENT GENERATORS

DIATHERMIC current generators are of two main types, one containing a spark-gap, and the other a triode valve. For medical diathermic treatment the spark gap type is more generally employed in this country and will be described first.

### *SPARK-GAP DIATHERMIC MACHINES*

*A spark-gap diathermic machine contains a step-up transformer, two or more condensers, a spark gap, an oscillator, a resonator and an amperemeter.* The plan (Fig. 40) shows the parts diagrammatically and their connections. One condenser is shown in the oscillating circuit. Two small condensers and an amperemeter are shown in the resonating circuit.

Fig. 41 represents a complete diathermic machine (of no special make) in a semi-diagrammatic manner. It will be seen that a transformer, a condenser, an oscillator and a resonator occupy the interior of a cabinet, while a spark gap and amperemeter are mounted on the exterior.

The transformer consists of a framework of soft iron and two coils of insulated wire. Of these coils the *primary* contains a relatively small number of turns. Its ends are connected to the terminals that lead to the main A.C. supply. The *secondary* contains many more turns than the primary.

The condenser consists of a number of metal plates, each one of which is separated from its neighbour by a layer of insulating material. Some machines contain more than one condenser in circuit with the transformer.

The oscillator represented in the figure is a flat coil of metal ribbon resembling a large clock-spring. In some machines it has the form of a bobbin coil of thick wire.

The expression "spark-gap" implies that there is but one space, or gap, for the sparks to bridge. In very small machines this is actually the case. In larger machines, however, there are at least two spaces, and more often there are three or four. They are grouped *in series* in the

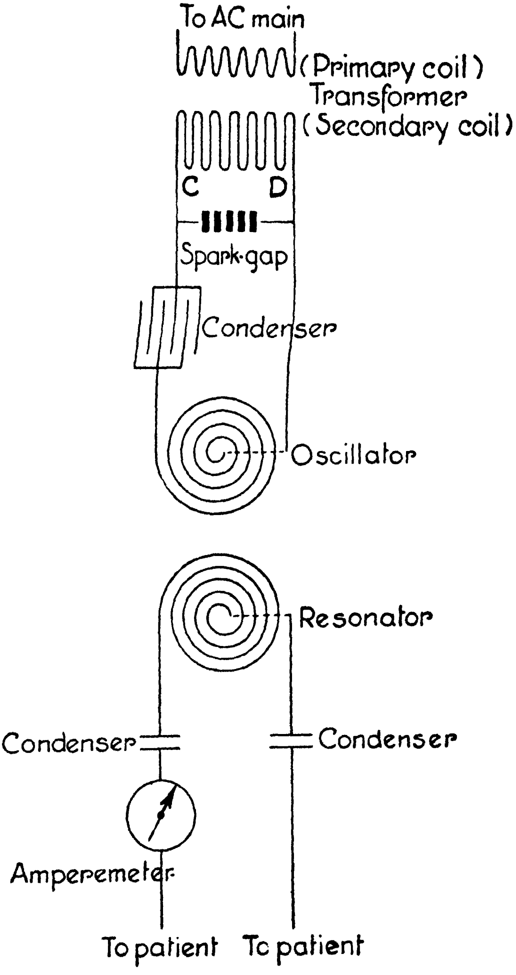

FIG. 40.—Plans of Circuits in Diathermic Machine. (From "Essentials of Medical Electricity": published by Henry Kimpton.)

circuit. In Fig. 41 the spark-gap is represented as containing four spaces. The spaces exist between metal discs. The discs are mounted on metal blocks to which are attached metal plates. These plates act as radiators and prevent the discs from becoming too hot. The connections between the condenser, oscillator, spark-gap and secondary coil of the transformer, can be seen in the figure.

When the oscillator is a flat coil the resonator also is a flat coil. But if the oscillator is a bobbin coil the resonator likewise is a bobbin coil. In circuit with the resonator there is an amperemeter. It is usual to have a small condenser in this circuit. In some machines there are two. They are not represented in the figure. The terminals to which the patient is connected are shown. The circuit containing the resonator is quite separate from that containing the oscillator.

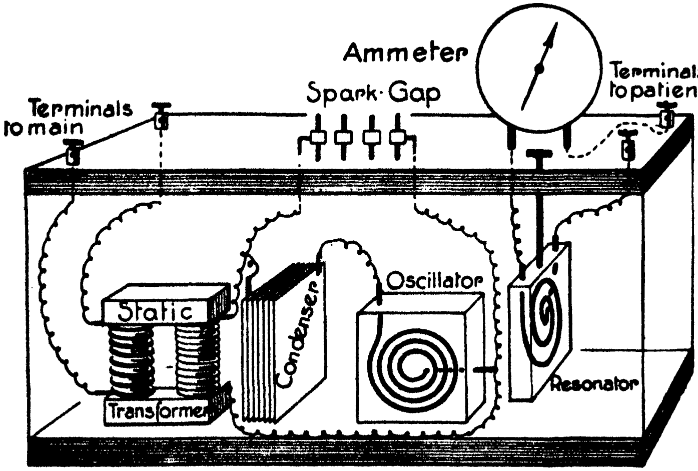

FIG. 41.—Cabinet containing the Constituent Parts of a Diathermic Machine and their Connections. (Semi-diagrammatic.) (From "Essentials of Medical Electricity": published by Henry Kimpton.)

On the top of the cabinet, in front of the amperemeter, is represented an ebonite disc. This is part of the coupling device. By rotating it the resonator can be made to lie directly over the oscillator or at right angles to it. In the first position the two coils are closely coupled, in the second they are uncoupled. The resonator can also be made to lie in any intermediate position. In some machines the oscillator occupies a horizontal position and the resonator is made to move in a plane parallel to it. The two coils are closely coupled when one lies directly over the other. When there is no overlapping they are uncoupled. When the oscillator and resonator have the form of bobbin coils, the diameter of one is larger than that of the other. They are closely coupled when one lies within the other, their long axes coinciding. Their coupling becomes progressively less close when the inner coil is withdrawn more and more from the outer. When one is completely withdrawn from the other they are uncoupled.

### The Equator Heavy-service Model

(*Medical Supply Association, Ltd.*)

Fig. 42 is an illustration of an actual machine, the Equator Heavy-service Model. The front panel of the cabinet has been removed so as to show the interior. On the marble slab (the " control panel ") that forms the top of the cabinet can be seen the spark-gap and the amperemeter. In front of the spark-gap are two terminals to which the patient is connected. In front of the amperemeter is a switch which opens and closes the circuit between the machine and the main A.C. supply. In the interior of the cabinet can be seen some of the other parts.

A brief description will be given of the component parts of the above-named machine. They are separately illustrated in Figs. 41–51. In a picture of the complete machine they cannot properly be seen.[1]

*The Step-up Transformer.* This is illustrated in Fig. 43. The primary winding has the lower position. One half of its layers are wound on the left and the other half on the right. The same is the case with the secondary winding ; this has the upper position in the figure. More perfect insulation is secured in this way. The difference of potential between the ends of the secondary coil reaches a value of 3,500 volts in the Equator machine. In order that this value may be attained, whatever the main supply voltage may be, the primary coil is tapped so that the number of turns in circuit with the main can be adjusted. This can be seen by examining the plan (Fig. 44). This plan also shows another coil in circuit with the primary winding. It is composed of insulated wire and wound around one side of an incomplete rectangular iron core. It is known as a "choke" coil. Its purpose is to prevent the current

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[1] The writer is indebted to the Medical Supply Association, makers of the machine, for the details which they kindly supplied.

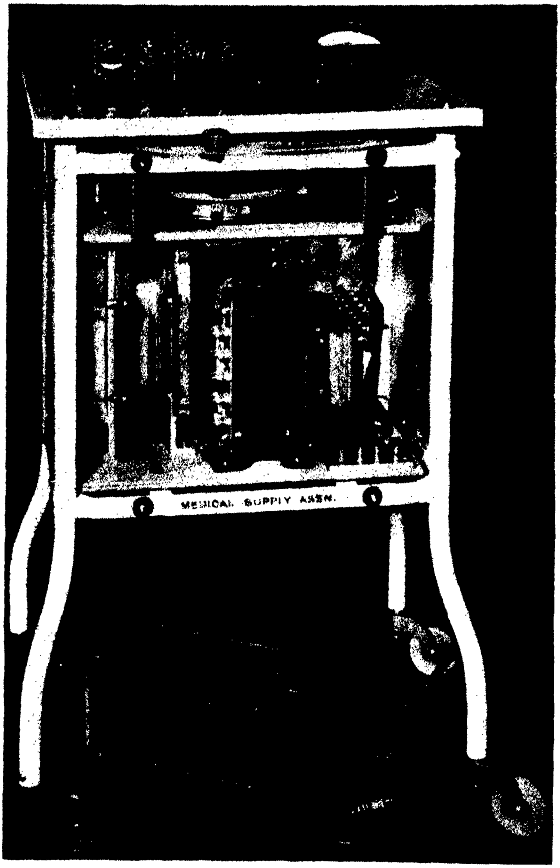

FIG. 42.—Equator Heavy-service Diathermic Machine.

in the primary coil attaining its maximum strength too suddenly—an event which would strain the insulation, particularly if the machine was made to yield a large current abruptly, instead of gradually.

*The Condensers.* In the Equator heavy-service diathermic machine there are *two* condensers in circuit with the secondary winding of the transformer. This is an alternative to a single condenser having double the capacity. These condensers are illustrated

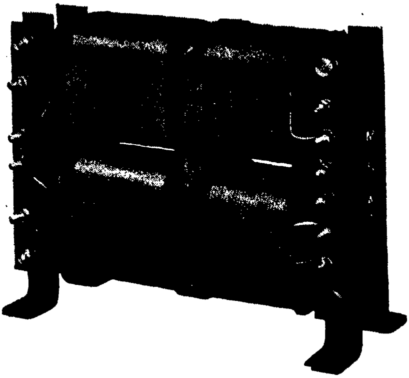

FIG. 43.—Step-up Transformer.

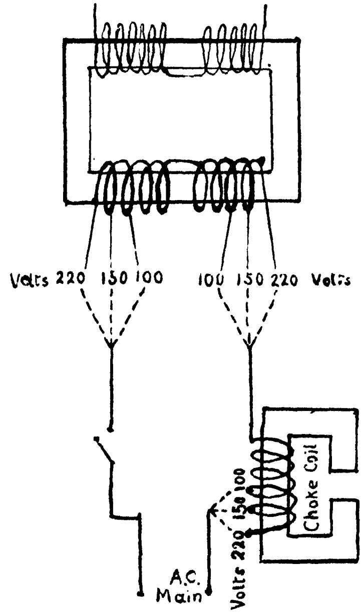

FIG. 44.—Plan of Transformer and Choke Coil.

in Fig. 45 in their supporting framework. They are quite separate from each other and kept apart by blocks of insulating material.

Each condenser consists approximately of twelve sheets of thin aluminium, each sheet being separated from its neighbour by a plate of insulating material (micanite). The aluminium plates

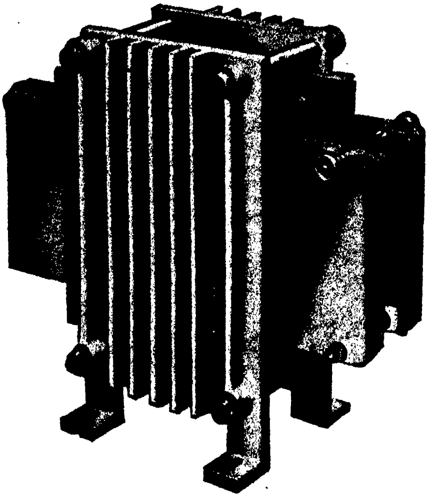

FIG. 45.—Two Condensers. (Insulated in Supporting Framework.)

project at each side beyond the insulating plates, as shown in the figure. Each condenser is clamped in position between supporting plates of aluminium. One of these plates can be seen in its entirety

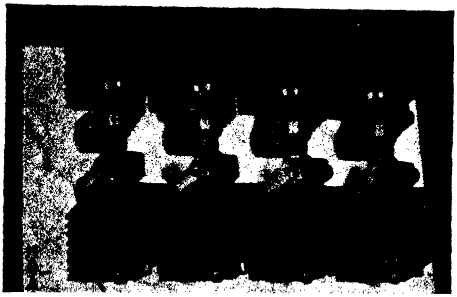

FIG. 46.—Spark-gap.

in the figure. They are provided with radiating vanes for the purpose of dissipating the heat produced in the condenser when the machine is in operation for lengthy periods. For the same purpose the projecting ends of the metal plates of each condenser are bent a little apart from one another. The capacity of each condenser is 0·0108 microfarad.

*Spark-Gap.* This is illustrated in Fig. 46. It contains four spaces. Each space is bounded by a pair of tungsten discs. The diameter of each disc is approximately 14 mm., and the width of each space is 0·254 mm. Each disc is mounted on a block of metal to which are attached a number of metal plates. These serve as heat radiators.

A portion of the spark-gap showing the constituent parts on each side of one of the spaces is represented schematically in Fig. 47,A.

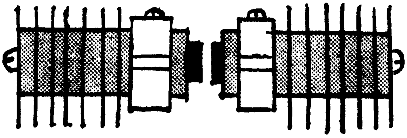

FIG. 47, A.—Portion of Spark-gap illustrated in Fig. 46. (Diagrammatic.)

A spark-gap containing only one space for the sparks to bridge is known as a *single* spark-gap. Those that contain more than one space are known as *multiple* spark-gaps. In these the gaps are *in series* in the circuit, not in parallel.

Another spark-gap, differing somewhat from that illustrated in Fig. 46, can be fitted to the Equator machine for working in small rooms or in hospital wards where noise created by sparks might cause disturbance. One section of the modified spark gap is illustrated schematically in Fig. 47,B.[1] It will be noted that the space bridged by the sparks is enclosed in a small chamber. The tungsten discs and the metal parts on each side are prevented from coming in contact by means of mica washers. These washers keep the discs at the correct distance apart.

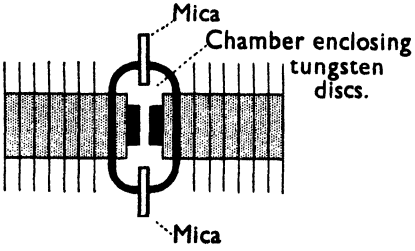

FIG. 47, B.—Spark-gap with Air-space in Closed Chamber.

*The Oscillator.* This is sometimes called the primary inductance coil. It is illustrated in Fig. 48. It is made of copper ribbon which is about ½ in. wide and wound in the form of a flat spiral like a clock-spring. There are 10 turns, and the maximum diameter is about 7 in. It is not necessary for the ribbon to be covered with insulating material because the turns are at a little distance from each other. *The oscillator is mounted on a support (which can be seen in Fig. 42 in the upper part of the cabinet).*

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[1] In machines by other makers the spark-gap is mounted *inside* the cabinet. In this position the noise of the sparks is muffled and it is not necessary to modify the design of the spark-gap.

*The Resonator (secondary inductance coil) is also a flat spiral.* It is made, not of ribbon, but of insulated stranded copper wire (Fig. 49). There are 24 turns, each turn being in contact with its neighbour. The maximum diameter is about 7 in. In the machine it lies just below the oscillator, but is separated from it by a sheet of insulating material (bakelite). It cannot be seen in Fig. 42.

In circuit with the resonator (see plan, Fig. 40) are two additional condensers, each having a capacity of 0·007 microfarad.

*The Amperemeter.* This is illustrated in Fig. 50. It is one of the thermocouple type. It is shown schematically in Fig. 51. The current to be measured passes along a thin narrow strip of metal, AB, and heats it. The heat is conducted to the point of contact of two dissimilar metals X and Y. At their point of contact they are joined to the metal strip. The current produced by the heating of the dissimilar metals passes along the coil V. This coil is mounted on an axle between the poles of a magnet (not shown in the plan), and when the current passes along the coil, the latter rotates through an angle, the degree of which depends on the strength of the current. The movement of the coil is communicated to a needle which moves over a scale. The scale is calibrated by passing galvanic currents of known strengths along the metal strip AB. When a diathermic current passes along the strip and the needle comes to rest, say, at the figure 500 it is said that the diathermic current has a strength of 500 milliamperes (*i.e.*, 0·5 ampere).

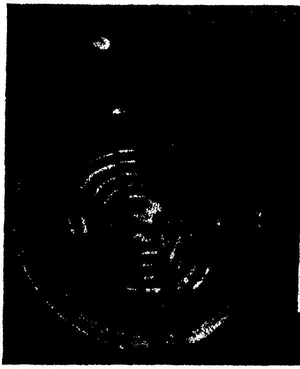

FIG. 48.—Oscillator.

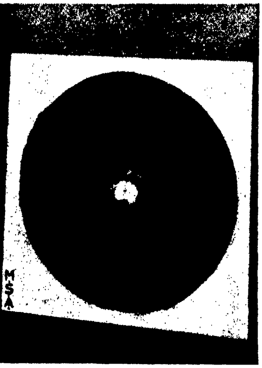

FIG. 49.—Resonator.

In the instrument illustrated in Fig. 50 there are two scales, one for reading current not exceeding 1,500 milliamperes. When the current is likely to exceed 1,500 milliamperes a shunt switch, which is mounted on the right side of the instrument, is moved to the position marked 6,000. This enables the current in the patient's circuit *to be conveyed to another metal which is connected in shunt with the first, and has a larger calibre. In this way currents of any value up to 6,000 milliamperes can be read.*

*The Coupling Device.* The resonator is fixed immovably in a horizontal position. The oscillator is movable in a horizontal plane. The movement is effected by shifting a disc to the right or to the left. This disc can be seen in Fig. 42 in front of the marble control panel. It is attached to the support that carries the oscillator. When it is moved as far as possible to one side the oscillator lies directly over the resonator. The two coils then are *closely coupled.* When it is moved an increasing distance towards the other side the oscillator moves more and more off the resonator. When it is moved as far as it will go, the oscillator is completely off the resonator. The two coils then are *uncoupled.* The disc with its attachment to the oscillator support is called the *coupling handle.*

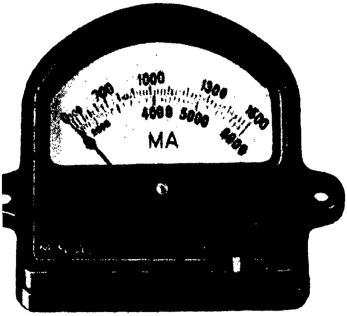

Fig. 50.—Amperemeter.

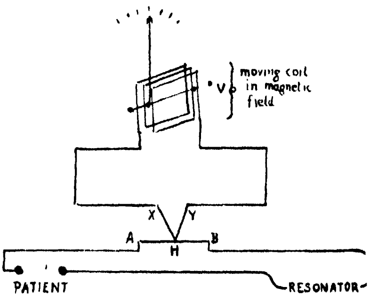

Fig. 51.—Plan of Amperemeter.

*Current and Voltage.* The frequency of oscillation of the current yielded by the machine under consideration is 667,000 cycles per second. The maximum voltage obtainable at the end of the resonator, when the circuit is open, and no patient included, is in the region of 600 to 800. It is much lower, however, when the circuit is closed and the body is in the circuit. The machine is constructed so that the electrical energy taken reaches a maximum of 800 watts. A watt is the product of 1 ampere and 1 volt. Thus if the machine is supplied from a 200-volt main, the maximum current it takes is 4 amperes.

### OTHER MACHINES OF THE SPARK-GAP TYPE

All diathermic machines of the spark-gap type are constructed on the same general plan although they exhibit certain differences in the design of some of the parts. Ten years ago the distinctive feature of each make of machine was the spark-gap. To-day, the design of this part is approaching standardisation, and most machines now manufactured possess multiple gaps in which the sparks pass between small discs of tungsten. The spark-gap already described (Fig. 46) is one of this kind. The main points of difference between machines of the spark gap type are seen in the design of the oscillator and resonator and the method of coupling them. In regard to their output, some yield currents of higher frequency than others. The Equator Heavy-service Machine and those about to be described are machines of full size constructed for heavy work in hospitals and places where many patients have to be treated in quick succession and large currents are needed.

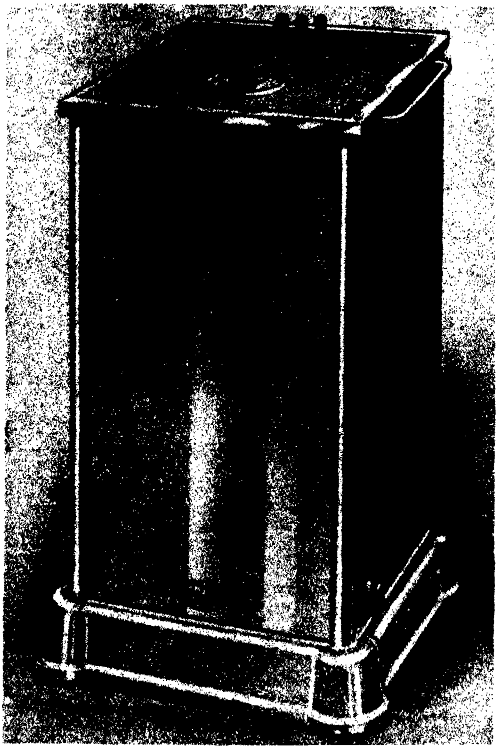

FIG. 52.—Diathermic Machine. "Therapeutic" Model.

### " Therapeutic " Model

*(Schall & Son, Ltd.)*

This is illustrated in Fig. 52. On the control panel, which forms the top of the cabinet, can be seen the following parts: a disc which can be rotated for the purpose of coupling the oscillator and resonator, the scale of the amperemeter, and *three* terminals for supply of current to the patient. The first and third are connected to the respective ends of the resonator, and the second to an intermediate point of the same coil. The maximum difference of potential is obtained between the ends of the resonator; it can reach a value of 2,000 volts when the circuit is open. The patient is brought into connection with the terminals attached to the *ends* of the resonator when the current has to traverse a long course in the body (*e.g.*, from one foot to the other) and overcome a high resistance. If a shorter course of lower resistance is provided for the current the patient is brought into connection with one end of the resonator and the intermediate point. There are four spaces in the spark-gap, each being 0·075 mm. in width. The diameter of each tungsten disc is 18 mm. The oscillator and resonator are flat coils. The former is stationary, and the resonator is movable. They are mounted horizontally. The current yielded has a frequency of 2,000,000 cycles per second. The machine is constructed to receive a maximum energy of 1,200 watts.

### The Dean Diathermic Machine

*(A. E. Dean & Co.)*

The interior of this machine is illustrated in Fig. 53. In the lowermost part of the cabinet can be seen the transformer. The spark-gap is mounted above it. It contains two spaces, each being 0·5 mm. wide. The tungsten discs are $\frac{5}{8}$ in. in diameter. There are two condensers in the oscillating circuit. They can be seen above the spark gap. The oscillator and resonator are bobbin coils. The resonator has a smaller diameter than the oscillator, and is mounted within it, the long axes of the two coils coinciding. In this position the resonator is closely coupled to the oscillator. As both coils are immovable, the patient would receive the maximum current when the machine was in operation. In order that the strength of the current may be regulated between zero and maximum a device of the following kind is adopted. The diagram (Fig. 54) will facilitate its explanation. RR′ is a coil of wire (a rheostat) in the circuit of the resonator. One of its ends R′ is connected to one of the patient's terminals. The other terminal is connected to a slider S which makes contact with the coil and can be moved along it so as to occupy any position between R and R′. When it is at R practically the whole current from

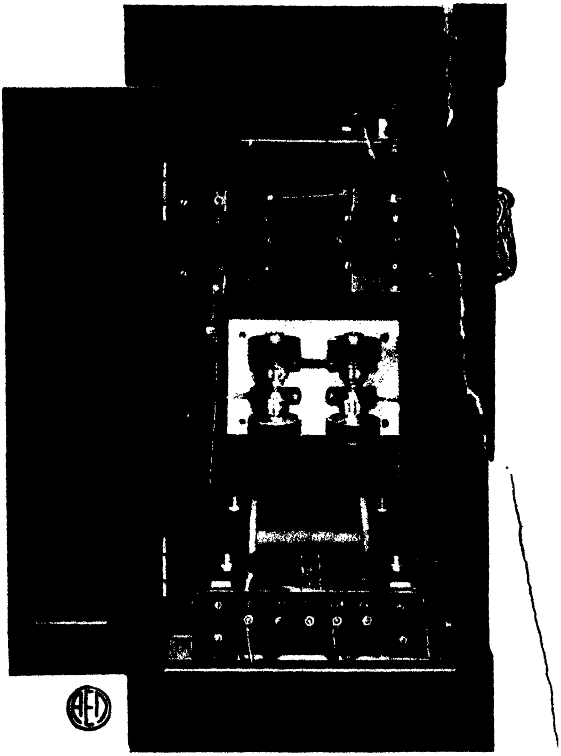

FIG. 53.—Dean Diathermic Machine.

the resonator will pass through the patient because the coil RR′ offers so high a resistance (impedance). But the further the slider is moved from R towards R′ the greater will be the impedance to the current in the patient's circuit and the weaker will be the value of the current ; and when the slider reaches R′ the patient will receive no current. In the machine itself the movement of the slider is effected by means of a rotating handle on the control panel.

The Dean machine illustrated in Fig. 53 is constructed to receive a maximum energy of 600 watts. The maximum voltage obtained at the patient's terminals, when the circuit is open, is about 2,000. The current oscillates with a frequency of about 500,000 cycles per second.

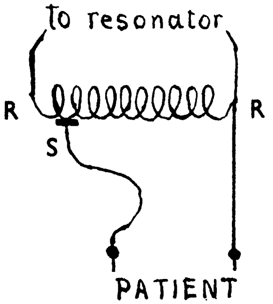

FIG. 54.

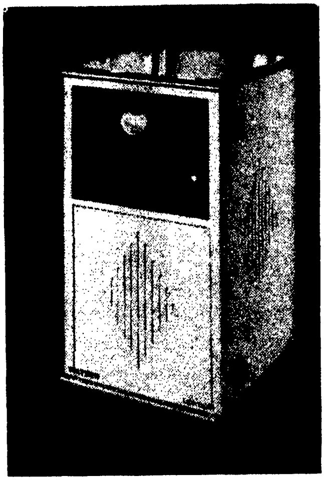

FIG. 55.—Sunic Junior Diathermic Machine.

### Sunic Junior Model

(*Watson & Sons, Ltd.*)

This machine is illustrated in Fig. 55. The oscillating circuit contains one condenser constructed in four separate sections in series, the whole being impregnated in wax. The spark gap contains two spaces, each being 0·125 mm. wide. The tungsten discs are $\frac{5}{8}$ in. in diameter. The oscillator and resonator have the form of bobbin coils. Each is wound on a tube of insulating material. The diameter of the resonator is smaller than that of the oscillator. The former is mounted within the latter, the long axes of the two coils coinciding. Both coils are fixed in a position of close coupling. There are two terminals for connection to the patient. The resonating circuit contains an amperemeter and one condenser. For the purpose of regulating the strength of the current to the patient between zero and maximum there is a rheostat in the resonating circuit. By means of a sliding contact the number of turns of the rheostat in the patient's circuit can be varied and the strength of the current thereby regulated.

The control panel is mounted on the front of the cabinet. There can be seen the scale of the amperemeter, the two terminals to which the patient is connected, and two handles which can be rotated. That on the left is for moving the sliding contact along the rheostat. By rotating the handle on the right the width of the spark gap can be varied. The width most generally used is that stated above. When it is narrower a lower maximum voltage is obtained at the patient's terminals, but a stronger current can be obtained provided the region of the body in the circuit has a low resistance. On the other hand, if the region has a high resistance, a higher maximum voltage is necessary in order to obtain the maximum current that the machine can supply to the part. The higher voltage can be obtained by widening the spark gap.

The machine is constructed to receive a maximum energy of 650 watts. The maximum voltage obtained at the patient's terminals, when the spark gap has the width stated above, is 700. The current oscillates with a frequency of about 1,000,000 cycles per second.

### The N. & W. Standard Machine

*(Newton & Wright, Ltd.)*

This machine is illustrated in Fig. 56. The back panel has been removed in order to show the parts in the interior.

The transformer is seen in the lower part of the cabinet. A single condenser is in the oscillating circuit. The oscillator is a bobbin coil of copper tube wound on a cylinder of insulating material. The resonator also is a bobbin coil which has a larger diameter than the oscillator. It is wound on an insulating tube. It is fixed in position.

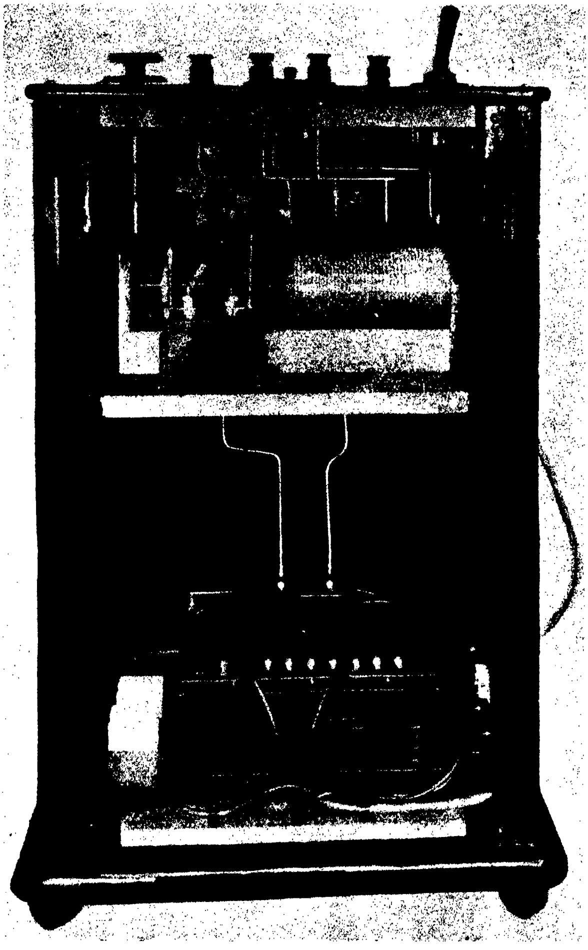

FIG. 56.—The N. & W. Standard Machine.

*The oscillator, however, can be made to slide into, or out of, the resonator, the movement being effected by turning the coupling handle which can be seen in the figure on the* left side of the control panel. The oscillator and resonator can also be seen; they are mounted on a platform in the cabinet. The oscillator is partially inserted into the resonator.

There are three spaces in the spark gap, each being 0·1 mm. wide. The diameter of the tungsten discs is $\frac{5}{8}$ in. When the width of the spaces has increased, after long usage, it can quickly be reduced to its correct value simply by turning a key.

The maximum energy received by the machine is 1,500 watts. The maximum voltage obtainable at the patient's terminals is about 1,200. The frequency of oscillation of the current can be adjusted between 550,000 and 820,000 cycles per second. This is effected by a tapping on the condenser. The entire condenser is taken into the oscillating circuit when the less high frequency is desired; a portion of it being excluded when the higher frequency is desired. Four terminals are connected to the resonator for attachment of the patient.

### The Standard "Intertherm" Machine

(*Stanley Cox Ltd.*)

This machine is illustrated in Fig. 57. On the control panel can be seen the amperemeter, and below it a rotating handle for coupling the oscillator and resonator. The patient is connected either to the two terminals on the right side of the panel or to those on the left side, according to his position in relation to the machine. Two additional terminals are provided near the lower end of the panel on the right side. The patient is connected to these terminals when he is to receive diathermy in combination with other currents (see p. 162).

There is one condenser in the oscillating circuit. There are three spaces in the spark gap, each being approximately 0·125 mm. in width. The diameter of each tungsten disc is $\frac{9}{16}$ in. The oscillator is a bobbin coil. It is fixed. The resonator also is a bobbin coil, but its diameter is smaller than that of the oscillator. The resonator can be moved so as to lie completely within the oscillator, the long axes

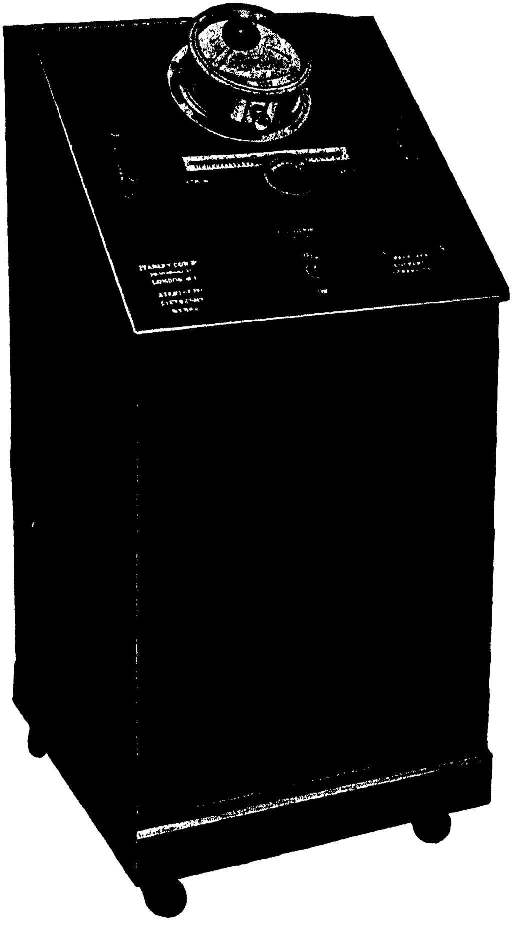

FIG. 57.—The Standard "Intertherm" Machine.

of both coils coinciding. In this position the coils are closely coupled. The resonator can also be moved so as to lie completely outside the oscillator; in this position the two coils are uncoupled. It can also be made to occupy any intermediate position. The movement is effected by turning the rotating handle. There is one condenser in the resonating circuit.

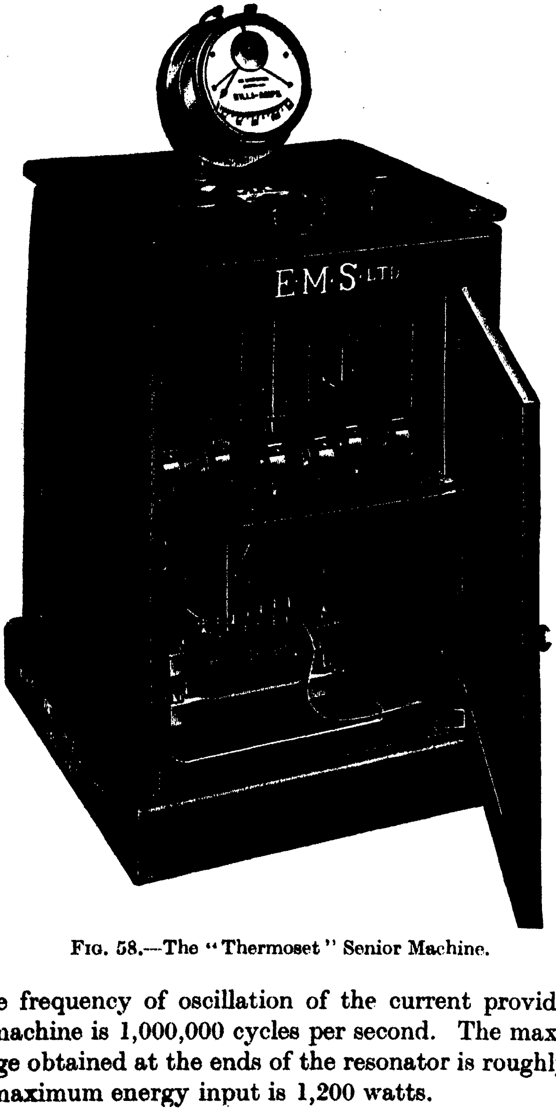

FIG. 58.—The "Thermoset" Senior Machine.

The frequency of oscillation of the current provided by this machine is 1,000,000 cycles per second. The maximum voltage obtained at the ends of the resonator is roughly 250. The maximum energy input is 1,200 watts.

### The "Thermoset" Senior Model

(*Electro-Medical Supplies Ltd.*)

This machine is illustrated in Fig. 58. On the control panel can be seen the amperemeter, a switch for opening and closing the circuit between the machine and the main, a rotating handle for coupling the oscillator and resonator, *and three terminals which are connected respectively to the ends and an intermediate point of the resonator. A single condenser is in the oscillating circuit. It is housed in an airtight case. The spark gap contains three* spaces, but in other respects it resembles those already described.

The oscillator is a cylindrical coil made of thin copper tubing. It is mounted with its long axis at an angle of 45° with the horizontal.

The resonator is a cylindrical coil of smaller diameter, and is mounted within the oscillator. By means of the coupling handle seen on the control cabinet (on the right side) the resonator is made to rotate so that its long axis makes an increasing wide angle with that of the oscillator. In this respect the machine differs from the others. The oscillator and resonator are separately represented in Fig. 59.

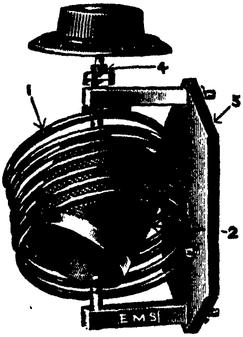

FIG. 59.

### The "Dreadnought" Machine

(*F. W. Read & Sons Ltd.*)

This machine is illustrated in Fig. 60. On the control panel can be seen the scale of the amperemeter, a rotating handle for coupling the oscillator and resonator, and five terminals. Three of these are in connection with the resonator, one being connected to one end, another to the other end, and the third to an intermediate point. Two of these three terminals are connected to the patient when it is desired to give diathermy alone. When it is desired to give diathermy in combination with treatment by other currents (see p. 163) the patient is connected to the other two terminals.

There are two condensers in the oscillating circuit. The spark-gap contains four spaces, each being 0·25 mm. in width. The diameter of each tungsten disc is $\frac{5}{8}$ in. The

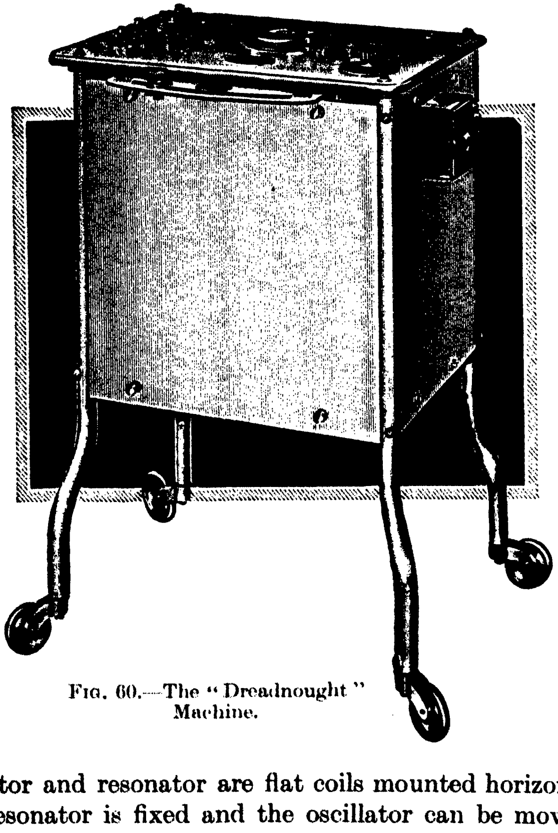

FIG. 60.—The "Dreadnought" Machine.

oscillator and resonator are flat coils mounted horizontally. The resonator is fixed and the oscillator can be moved by the coupling handle of which the end can be seen in the figure just below the control panel.

This machine yields a current which oscillates with a frequency of 750,000 cycles per second. The maximum voltage output is 4,500. The input energy is 1,265 watts. A special feature of this machine is the provision of an additional condenser and inductance to enable the patient's electrodes to be connected to a source of galvanic, faradic or sinusoidal current so that diathermic treatment can be given at the same time as treatment by one of the three last-mentioned currents. It is necessary, as will be explained hereafter (p. 163), to provide an additional condenser and inductance in order to prevent the diathermic current passing through the source of one or another of the additional currents, and *vice-versâ*.

## MACHINES OF AMERICAN DESIGN

Machines of American manufacture differ from those of European make in the methods adopted for regulating the strength of the current received by the patient. Fine adjustments are made by varying the width of the spaces of the spark gap. Each space can separately be varied in width, and some machines contain a master-key which enables the width of all the spaces to be varied synchronously. Coarser adjustments are made by means of the transformer. The primary winding is tapped so as to include a greater or smaller number of its coils in the circuit of the supply current from the A.C. main.

When the patient is to receive the diathermic current the spark-gap spaces are closed. The handle that regulates the amount of current received by the primary circuit of the transformer is placed at its " weak " position. When the switch is opened the spark-gap spaces are gradually opened to their maximum width and the amperemeter in the patient's circuit is read. If the current is insufficient, the spark-gap spaces are again closed and the transformer handle is moved to its next position The spark-gap spaces are again opened. If the current is still insufficient the same procedure is repeated.

Some machines are fitted with a cylindrical coil oscillator of considerable length, and arrangements are made so that a relatively small number of turns are included in the oscillating circuit when it is desired to obtain a diathermic current. In the remaining turns the voltage attains a higher value suitable for procuring sparks for electrodesiccation. American machines usually contain no separate *resonator circuit* in which to place the patient when diathermy is given. He is connected to the ends of the oscillator.

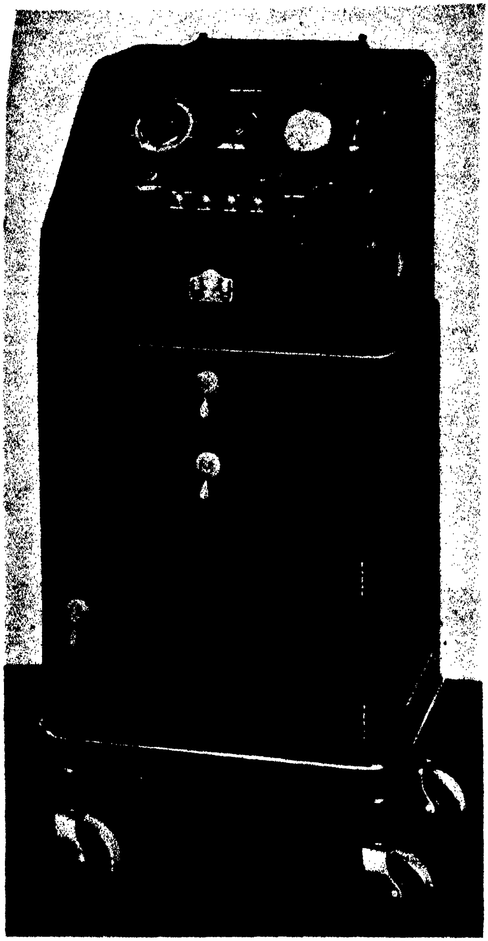

Fig. 61.—Diathermic Machine by H. G. Fischer & Co., Chicago.

A full-size machine made by H. G. Fischer, of Chicago, is illustrated in Fig. 61. The following particulars of the "G2" model were kindly given by the firm. The input energy is 370 watts. There are two condensers in the oscillating circuit; they are made of mica and copper sheets. There are four spaces in the spark gap, bounded by tungsten discs ⅜ in. in diameter. The width of the spaces can be varied. The oscillator is a cylindrical coil. There is no separate resonator. The patient is connected to the oscillator; there is a condenser in the circuit between him and the oscillator. The frequency of the diathermic current is 1,100,000 cycles per second. In the solenoid it is possible to obtain maximum voltages of 1,000, 2,500, or 5,000, according to the number of turns of the oscillator included in the circuit.

### MACHINES OF SMALLER SIZE

Many manufacturers also construct smaller machines than those just described. They provide smaller currents than those yielded by the large heavy-service models. They are suitable for light work in hospitals and in private.

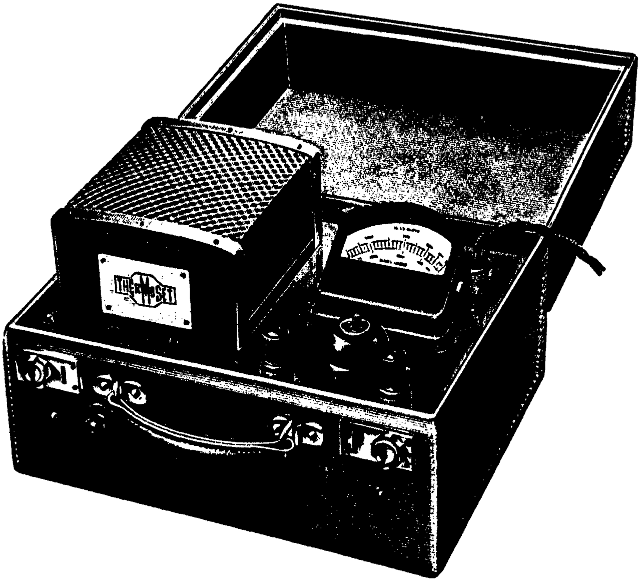

Fig. 62.—"Thermoset" Junior Machine. (Obtained from block provided by Electro-Medical Supplies, Gt. Portland St.)

Some are portable and can be employed for treating patients in their own homes.

A portable machine is illustrated in Fig. 62.

Small machines will stand up to their work provided they are not called on to treat large regions with large electrodes. If they are used in this way they will take more electrical energy from the main than they are constructed to receive. They will overheat and the diathermic current they yield will gradually fall to zero.

### DIATHERMIC MACHINES OF THE VALVE TYPE

The principle underlying the working of machines containing triode valves has already been described in Chapter III. In the explanatory diagram (Fig. 63) a triode valve is represented at V. It is in a circuit (the so-called valve circuit) containing the secondary coil of a step-up static transformer, and an inductance coil II′. Coupled to this coil is an oscillator OO′. The oscillator is in a circuit (the so-called oscillating circuit) containing a condenser CC′. A resonator RR′ is coupled to the oscillator. The circuit in which it is placed (the so-called resonating circuit) contains a condenser D and the body.

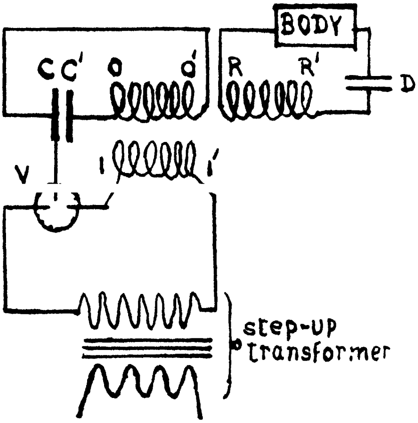

FIG. 63.—Scheme of Circuits in Valve Machine. V, Valve; CC′, Condenser in Oscillating Circuit; OO′, Oscillator; II′, Inductance in Valve Circuit; RR′, Resonator; D, Condenser in Resonating Circuit.

An actual machine is illustrated in Fig. 64. In the interior of the cabinet can be seen the triode valve; it is marked with the figure 9. It is illustrated separately in Fig. 65.

A plan of the parts comprising the machine is shown in Fig. 66. The parts are numbered in correspondence with the same parts in Fig. 64. The plan shows the presence of additional coils and amperemeters. Various parts are connected to the earth. These additional parts are introduced for various electrotechnical reasons which need not be considered here.

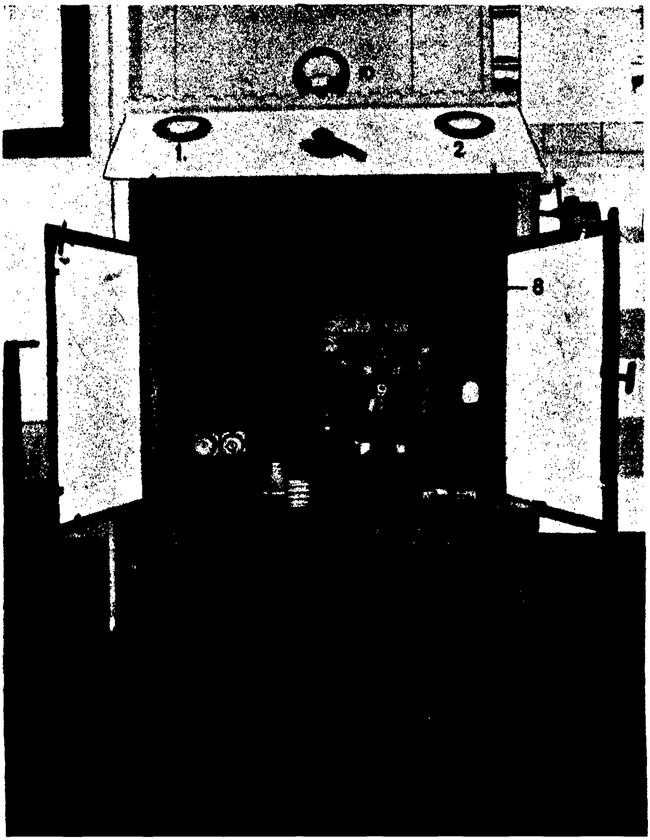

FIG. 64.—Diathermic Machine with Three-electrode Thermionic Valve. (Nederlandsche Seintoestellen Fabriek, Amsterdam.)

When the patient is introduced into the resonating circuit for the purpose of treatment, the first procedure is to switch on the current which heats the filament of the valve. This current is derived from a small transformer. It is represented in the plan (Fig. 66). It is quite separate from the main transformer which supplies electrical energy to the machine.

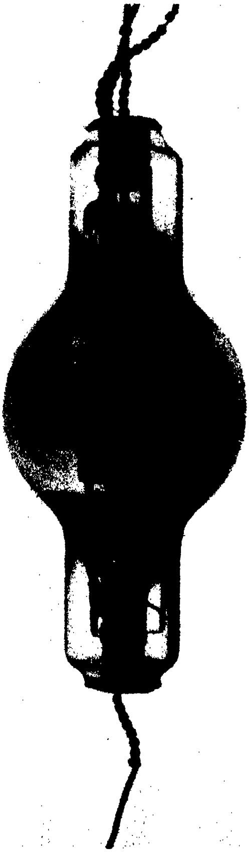

Fig. 65.—Triode valve.

SPARK-GAP MACHINES IN ACTION

All machines of the spark gap type must be supplied with *alternating* current. If the current provided on the main is *direct* it is necessary to obtain a rotary converter. This is a combined motor and dynamo. When it is connected to the D.C. main the armature revolves and provides alternating current.

When a diathermic machine is connected to the source of alternating current and the switch opened, a continuous hissing. crackling sound is heard. It is caused by the passage of sparks across the spaces between the tungsten discs of the spark-gap. The metal parts of th grow gradually hotter. The tungsten discs attain a higher temperature than the other parts, but owing to the fact that they are welded on large metal blocks which are provided with radiating plates the discs do not overheat, provided the machine does not receive more current than the maximum amount which the transformer is constructed to receive.

If a metal rod electrode is held in each hand and connected to the patient's terminals and the machine set in operation the amperemeter needle will not move from its zero position when the oscillator and resonator are uncoupled. But when the current regulator is moved so as to couple the two coils more and more closely the point of the needle will move over the scale and eventually indicate a current of 0·7 to 0·8 ampere if the machine is of full size. If large plate electrodes were placed on opposite aspects of the trunk a current of much higher value, viz., 2, 3 or even more amperes would be indicated because the resistance (impedance) of the portion of the body in the circuit is much lower than that of the upper limbs.

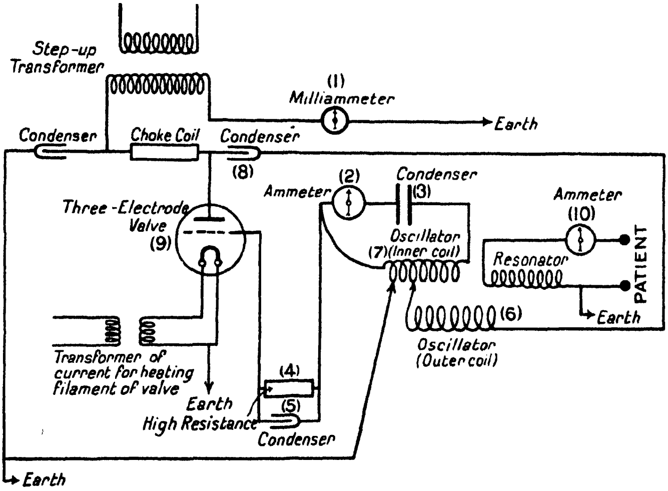

FIG. 66.—Plan of Machine illustrated in Fig. 64.

If two wires are connected to the terminals from which the diathermic current is taken, and their free ends brought near to one another, a torrent of thick sparks will pass across the gap.[1] In some of the full-size machines the ends

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[1] Experiments of this kind must be practised with caution. When the oscillator and resonator are closely coupled in order to ascertain the maximum length of spark, the ends of the wires must not be allowed to touch one another. If the current were short-circuited in this way the amperemeter might be damaged and the insulation strained between the coils of the transformer and the plates of the condenser.

*of the wires have to be brought as near together as* $\frac{1}{16}$ *in.* before there is a passage of sparks. In others, the sparks will pass when the ends are brought $\frac{1}{8}$ in., or even $\frac{1}{4}$ in., from each other. As soon as the gap is just narrow enough and the sparks bridge the air space, the resistance to their passage diminishes. Consequently the gap can be made a little wider without stopping the passage of the sparks. The sparks, though longer, will be thinner than those which passed across the narrower gap.

The maximum air space that the sparks will bridge depends on the maximum voltage attained at the ends of the resonator. Some machines produce higher voltages than others. In the models that have been described the approximate values were stated.

### CARE OF THE MACHINE

Present-day diathermic machines fitted with open spark gaps of the type described need little attention beyond occasional dusting. After they have been in daily use for some weeks the space between the tungsten discs may be a little too wide. When this occurs there will be, now and again, a momentary cessation in the passage of the sparks, particularly when the machine is starting its day's work and the tungsten discs are still cold. Re-adjustment of the spark gap is not difficult, and most machines are provided with feeler gauges for the purpose of obtaining the correct width of the spaces.

The amperemeter should be inspected occasionally in order to see whether the needle is exactly opposite the zero figure when the machine is not in action. In most machines the instrument is provided with a screw adjuster for the purpose of bringing the needle, when necessary, to its correct zero position.

The power of the machine to give its maximum output after many months of daily work depends on the insulating efficiency of the material used as the dielectric for the main condenser in the oscillating circuit. Perforation of the dielectric by sparks was not a rare event in the life of the earlier machines. Although perforation does not occur nowadays the dielectric does not retain its full power indefinitely, and eventually the machine fails to give its full output. But the material now used in the construction of the condenser retains its full efficiency for periods as long as two or three years.

It is a good plan for the operator occasionally to test the output of his machine by passing the current through himself by way of cylindrical electrodes grasped in the hands. This should be done when the machine is new, and the reading of the amperemeter noted when the machine is adjusted to give its maximum output. This reading should be noted and afterwards compared with those observed from month to month.

If the machine is not one of full size it should not be used for heavy service. If it is employed in the treatment of many patients in succession, with only short intervals between successive séances, it is likely that the spark gap and other parts will overheat. Overheating is likely also to occur if the electrodes are of the maximum size intended for use only with large machines. The operator will know when the spark gap is growing too hot because the current in the patient's circuit will begin to diminish. If the machine is then allowed to continue its work the current will further diminish and eventually it may reach zero. The following is the explanation. In the normal working of the machine the air in the space between the tungsten discs is momentarily but intensely heated by the sparks that accompany each discharge of the condenser. The heat, however, is quickly conducted away by means of the metal blocks to which the tungsten discs and radiators are attached. On the other hand, if the machine continues to receive too much current the heat will not be conducted away sufficiently quickly from the space between the discs. The result will be a progressive fall of resistance of the air in the space. The voltage to which the condenser is charged will progressively diminish. Eventually the air in the space will have so low a resistance that the condenser will be charged scarcely at all. Consequently there will be very little current in the resonating circuit. At the same time the reduction of the resistance of the spaces in the spark gap will increase the current in the transformer, overheat its wire coils and damage their insulation.[1]

### NOTES ON THE VARIOUS MODELS OF DIATHERMIC MACHINE

For the practice of medical diathermic treatment, either a valve machine or one of the spark gap type may be employed. Valve machines have the following advantages. They work without emitting a sound. They require no attention beyond removal of dust and occasional cleaning of the glass of the valve. There is much less waste of energy in the transformation of the low-frequency supply current into the outgoing high-frequency current. On the other hand, the life of a triode valve is limited. After the expiration of, say, 1,000 working hours a new valve must be fitted. Triode valves are costly to replace.

*The amount of attention that had to be paid to machines containing spark gaps of the closed type, and the likelihood of overheating, induced some workers to employ valve machines for medical diathermic treatment.* But the spark-gap machines now manufactured give so little trouble and need so little attention that valve machines are seldom used in this country. English manufacturers do not make them, as far as the author has been able to ascertain, except for other electrothermic purposes, such as short-wave treatment and electrosection.

In regard to the choice between large and small machines the limited usefulness of the latter has already been mentioned. Small machines are unsuitable for the administration of diathermic treatment on a condenser couch (p. 152). When they are connected to a couch of this kind the patient receives an inappreciable amount of current. The smallest machines are suitable only for surgical diathermy (electrocoagulation).

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[1] In the machines originally constructed, overheating was a common occurrence, even if they were of full size. Much ingenuity was expended in the endeavour to prevent it. In one machine, originally constructed by Siemens, the sparks passed between silver plates 2 in. in diameter, mounted on massive copper discs. This type was not entirely successful for heavy service. Further, the mica washers which kept the silver plates apart, were occasionally perforated by the sparks. French makers introduced a spark gap which was enclosed in a chamber containing a supply of coal gas. This was one of the so-called "closed" spark gaps. The sparks decomposed the hydrocarbons in the coal gas, forming hydrogen—a gas which is a better conductor of heat than air—and carbon. The carbon took the form of soot which gradually filled the chamber. It was necessary, therefore, to dissemble the parts at frequent intervals for the purpose of cleaning. In another type of spark-gap a supply of methylated spirit was made to trickle slowly into the space between the metal discs. The sparks decomposed the alcohol and formed hydrogen. American manufacturers have always fitted spark gaps of the type which now are used by European makers.

# CHAPTER VII

## HEATING THE BODY BY THE DIATHERMIC CURRENT

### Introduction

WHEN a region of the body is introduced into the circuit of a diathermic current it is easy to demonstrate a rise of temperature of the skin. The current is employed, however, for the purpose of raising the temperature of parts which are beyond the reach of heat derived "ready-made," as it were, from external sources. It is necessary, therefore, to obtain evidence of heating of the deep parts and inquire the degree to which they can be heated. There are a few regions of the living body into which it is possible to insert thermometers. But in most parts it is impracticable or impossible to introduce thermometric instruments and it is still undecided whether their temperature can be raised by the current. On theoretical grounds it is difficult to reach a conclusion on account of the peculiarities of the diathermic current and the complexity of the body as a conductor. The writer believes that for the clinician the most helpful way of beginning the study of the heating of the living human subject by the diathermic current and approaching the questions that remain undetermined, is to place in the circuit, first, the upper extremities; afterwards, the lower extremities, and lastly a portion of the trunk, noting the rises of temperature that occur in the parts where it can be measured. Experiments of this kind are described below.

### HEATING OF THE UPPER LIMBS

The upper limbs can be placed in circuit in the following way. Two cylindrical electrodes are connected to the terminals of the diathermic machine and one is grasped in each hand. The current is started and gradually increased.

Those who are unfamiliar with diathermy should hold the electrodes themselves and experience the thermic sensation evoked by the current. Heat is felt first in the wrists and afterwards in the forearms and upper arms. The wrists grow gradually hotter and the sensation may become unbearable in these parts when the current attains a strength of 0·6 to 0·7 ampere. But if the strength is insufficient to cause undue heating of the wrists a sensation of heat will gradually appear *in other parts* of the body after the current has been passing for some minutes. Eventually it will be felt in the entire body.

After the sensation has been personally experienced an adult subject should be placed in circuit in the same way and the current increased to the same strength as before. The operator will soon be able to detect the heightened temperature of the limbs by placing his hand in contact with the skin. The higher degree of heating of the wrists, in comparison with the arms, will be quite evident. The operator may also be able to detect a higher degree of heat on the *front* of the forearm and elbow than on the *back* of the same parts. The differences can easily be demonstrated by means of thermometers. After the current has been passing for fifteen or twenty minutes a rise of temperature can be demonstrated in other parts of the body.

The figures obtained in an experiment of this kind are given below :

EXPERIMENT 1. The subject was seated and the arms extended. A cylindrical electrode was grasped in each hand. A current of 0·4 ampere was passed for twenty minutes. The heat was insufficient to cause discomfort. The following rises of temperature were noted :—

| | |
|---|---|
| Wrist | 12·8° (from 92·2 to 105). |
| Front of forearm | 7·2° (from 91·4 to 98·6). |
| Back of forearm | 6·8° (from 90 to 96·8). |
| Front of upper arm | 3·6° (from 93·2 to 96·8). |
| Axilla | 4·0° (from 95 to 99). |
| Mouth | 4·8° (from 94·2 to 99). |
| Groin | 2·2° (from 94·0 to 96·2). |
| Popliteal space | 3·2° (from 93·6 to 96·8). |

In this experiment two events were witnessed ; first, the heating of parts of the body *in* the circuit of the current, and second, the heating of parts of the body *outside* the circuit. The circuit comprised the upper limbs (excluding the fingers) and the upper portion of the chest between the shoulders. Although the remaining parts of the body are also able to conduct the current they will be regarded as *outside* the circuit because the proportion of current that oscillates in them, particularly the more distant parts, must be too minute to produce measurable heat.

The rise of temperature of the upper limbs is easily explained. It is due to the production of heat by the current in overcoming resistance in its circuit. This may be called " joule " heat.[1] The rise of temperature of the other parts that are outside the circuit is due to the conveyance (*convection*) of heat from the hot limbs by the circulating blood. This may be called " convected " heat. The heating of the body by the diathermic current is influenced in no small degree by the circulation. This subject is so important that it will receive detailed consideration later in the present chapter.

The experiment shows also that different parts of the limbs are not heated to the same temperature. The wrist attained a higher temperature than the other parts. Further, a higher temperature was reached on the *anterior*, than on the *posterior*, aspect of the forearm, in spite of the fact that both thermometers were placed the same distance from the wrist.

One reason for the difference in the degree of heating at different distances along the limb is evident. In the region of the wrist the limb is smaller in cross-sectional area than in the upper part of the forearm, and in the subject of the experiment the cross-sectional area of the last-mentioned part was smaller than that of the upper arm. Consequently the current attained a higher density in the wrist than in the forearm, and a higher density in the forearm than in the upper arm.

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[1] The expression " joule heat " is a useful abbreviation for heat produced by an electric current in overcoming resistance. It will be remembered that James Prescott Joule established the numerical relationship between electrically produced heat, the strength of the current and the resistance of the circuit.

The reason for a higher temperature on the anterior aspect of the forearm than on the posterior is less obvious. In all probability the difference is due to the fact that the tissues occupying the anterior portion of the forearm (mainly muscles) offer less resistance (impedance) to the current than those that occupy the posterior portion (mainly bones). Since the muscles and bones are grouped *in parallel* in relation to the direction of the current, it may be concluded that the less resistant muscles reached a higher temperature than the more resistant bones. The current would tend to heat the skin and fasciæ of the front and back of the forearm to the same degree at the same distance from the wrist. But as the muscles presumably were heated to a higher temperature than the bones, the skin over the muscles was additionally heated, *by conduction*, to a higher temperature than the skin over the bones.

The high impedance of bone is another reason why the wrist is heated to a higher degree than other parts of the limb. The greater part of the cross-sectional area of the wrist is occupied by osseous tissue.

Whatever the region to which the electrodes are applied the current will encounter tissues of different impedance. The impedance of a tissue is one of the factors determining the degree to which it can be heated. The current, in fact, can heat one tissue several degrees while another on the path of the same current is heated a little or scarcely at all. The relative impedance of different tissues are given on p. 126, but it may be stated, in passing, that fat offers the highest, and blood the lowest, impedance. The impedance of fat is nearly twenty times higher than that of blood; that of bone is about six times higher, and that of muscle is only a slight degree higher.

A most important matter now remains for inquiry. In the experiment the temperatures measured were those of the skin. It is necessary to state the evidence that enables us to conclude that the heat is not restricted to the superficial tissues. The evidence is the following.

(1) In the experiment already described it was noted that a higher temperature was obtained on the *flexor* than on *the extensor aspect of the* forearm. It can also be shown *that the flexor aspects of the* wrist and elbow *attain a higher temperature than the extensor. If the current were restricted to the skin and superficial fascia these differences* would not be observed. They have already been explained on the assumption that the deep parts (muscles and bones) are heated as well as the skin and superficial fascia.

(2) When the current attains a high density in the wrists the sensation is not merely thermic: it has a peculiar and unpleasant aching character, quite different from that felt when the skin is heated to the same temperature by hot packs. The additional sensation may be attributed to the heating of the bones of the wrist.

(3) When the current passes along the upper limbs it is unlikely that the general temperature would rise to the values obtainable (*e.g.*, a rise of 4·8° in the mouth, as in Experiment 1) if the current were restricted to the skin and superficial fascia. It will be shown later that large areas of the skin of the trunk can be heated many degrees without producing more than a very slight rise of the oral temperature.

(4) The writer is unaware of any experiments on the arms of living human subjects in which a thermocouple was inserted into the muscles. But an experiment of this kind has been conducted on the leg and a rise of temperature was demonstrated. This experiment is described later (p. 115).

There are other ways of including the upper limb, or a portion of it, in the circuit. One is to place the electrodes on opposite aspects. When they have a relationship of this kind to the limb, and the current is started, the experiment differs in three ways from that in which the electrodes are situated at opposite ends of the limb. In the first place the conductor, *i.e.*, the mass of tissue in circuit between the electrodes is quite different in shape. In the second place, there are paths for the current, not only in the tissues directly included between the electrodes, but also in the outlying tissues that are uncovered by the electrodes. Thirdly, the tissues of different resistance are grouped *in series* rather than in parallel. These three points of difference will be considered separately.

(1) Assume that the electrodes are placed on the anterior and posterior aspects of the forearm. The mass of tissue between them is short in its antero-posterior measurement, corresponding to the distance between the electrodes. It is short also in one of its lateral measurements that correspond to the width of the electrodes. But it is relatively long in its other lateral measurement—that corresponding to the length of the electrodes. On the other hand, when the electrodes are placed at the *ends* of the upper limb, there is a long conductor between them, but one which is narrow in its other dimensions.

(2) When the electrodes are applied to opposite aspects of the limb there is another difference, apart from dimensions, that does not exist when the electrodes are placed at opposite ends of the limb. Assume that one electrode is placed on the middle third of the anterior aspect of the forearm, the other occupying a corresponding position on the posterior aspect, as indicated schematically in Fig. 67. There are paths for the current, not only in the tissues directly included between the electrodes, but also in the outlying tissues proximal and distal to the electrodes. The former may be called the *direct* paths ; they are indicated in the figure by continuous lines. The latter may be called the *outlying* paths ; they are indicated by dotted lines. There are no outlying paths when the electrodes are situated at the *ends* of the limbs as in the experiment already described.

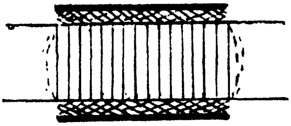
FIG. 67.

When the electrodes are on *opposite* aspects of the forearm and the current gradually increased, the skin under the electrodes will become quite hot. It may be assumed that the other tissues between the electrodes will rise in temperature. But it is unlikely that the tissues on the outlying paths will be heated by the current, except perhaps those that are just beyond the electrodes.

(3) When the electrodes are placed on opposite aspects of the limb the tissues of different resistance are grouped more *in series*, whereas they are grouped more *in parallel* when the electrodes are placed at the ends of the limb. It may be concluded, therefore, that the current will heat the bones of the forearm to a higher degree than the muscles when the electrodes are placed on the anterior and posterior aspects. It will be remembered that the reverse is the case when they are placed at the *ends* of the limb. The following experiments show the different degrees of heating of the anterior and posterior aspects of the elbow, according to the position of the electrodes.

EXPERIMENT 2. One electrode was placed at the back of the elbow, the other on the anticubital fossa. A current of 1·4 amperes was passed for ten minutes. The temperature at the side of the olecranon rose 12° (from 83 to 95); that of the anticubital fossa rose 9° (from 89 to 98).

EXPERIMENT 3. One electrode encircled the upper arm near the shoulder and the other encircled the wrist. A current of 0·8 ampere was passed for ten minutes. The temperature at the side of the olectranon rose 6°, while that of the anticubital fossa rose 11°.

Reasons have been given for concluding that the current is not restricted to the superficial tissues when the current passes longitudinally in the upper limb, *i.e.*, between its opposite ends. There is evidence also to show that the current is not restricted to the superficial tissues when it passes *transversely* in the limb, *i.e.*, between its opposite aspects. If the current were restricted to the superficial parts one would expect a higher temperature under the *edges* than under the *centre* of the electrodes, and at the same time a higher temperature of the *uncovered* skin between the electrodes than of the *covered* skin under the electrodes. But experiments on the forearm show that these expectations are not fulfilled. In Experiment 4 the covered skin reached a higher temperature than the part between the electrodes where it was uncovered. In a later experiment (No. 5) the skin under the edge of the electrode did not attain a higher temperature than that under the central portion.

EXPERIMENT 4. One electrode was placed on the flexor aspect of the forearm and the other on the extensor aspect. A current of 0·4 ampere was passed for 15 minutes. The temperature of the flexor aspect rose 9° (from 84·8 to 93·8). The temperature of the extensor aspect rose 9·6° (from 84·2 to 93·8). The temperature of the uncovered skin of the lateral aspect of the forearm rose 2·8° (from 84·8 to 87·6).

There is now another matter of importance to be considered when electrodes are placed on *opposite* aspects of a part. It has already been learnt that the path of high-frequency currents in metal conductors is restricted to a very thin superficial layer, whereas in electrolytes it passes along the deeper parts as well. When the body is included in the circuit of a diathermic current, metal conductors and electrolytes are in apposition; this is the case when, for example, plate electrodes are placed on opposite aspects of the forearm. It is necessary to inquire whether the current in its passage between the electrodes and the tissues is restricted to the edges of the electrodes, or whether it also passes between the tissues and other parts of the electrodes. The writer has endeavoured to obtain information on this matter by conducting experiments of the following kind. One electrode was placed on the extensor aspect of the forearm. It was separated from the skin by a pad soaked in salt solution. The other electrode was placed on the flexor aspect. It was separated from the skin by three small pads, quite separate from each other, one being placed under the central portion of the electrode and the others under the ends of the electrodes. The arrangement is indicated schematically in Fig. 68. A thermometer was placed between the central pad and the skin, and another was placed between the skin and the pad under the end of the electrode nearest to the wrist. The current was gradually increased. The temperatures observed are given below :—

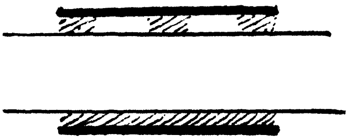

FIG. 68.

EXPERIMENT 5. The forearm measured about 8 in. in length. Each electrode measured 6 in. by 2 in. When they were in position on the anterior and posterior aspects of the forearm the distance between them was about 2½ in. at their ends near the elbow, and 2 in. at their ends near the wrist. The following temperatures were observed under the central pad and under the peripheral pad, first before the current started, and afterwards at three-minute intervals

Central pad—
88·6 92·2 94·0 97·8 101·2 103 (total rise = 14·4°)

Peripheral pad (near wrist)—
87·8 89·6 93·2 96·0 98·6 99·4 (total rise = 11·6°)

It will be observed that the temperature rose more under the central than under the peripheral pad. This must not be explained by assuming that a greater proportion of the current necessarily passes between the central parts of the electrodes. In the region of the wrist most of the tissue is bone ; in the middle of the forearm most of the tissue is muscle. Therefore the current encounters a higher impedance in the region of the wrist and does not heat it as much as the less resistant parts of the middle of the forearm. It will be noted that the higher resistance of the wrist and the lower resistance of the middle of the forearm are grouped in *parallel.*

Experiments of the kind above described show that the diathermic current is not restricted to the tissues between the edges of the electrodes when the latter are on opposite aspects of a part, facing one another and in approximately parallel planes. If the tissues between them were homogeneous it is likely that there would be little difference between the degrees of heating of the central and peripheral parts. One reservation, however, must be made. In the experiment just described the electrodes were close together in comparison with their size. If they had been much smaller a larger proportion of the current would probably have passed between the peripheral than between the central parts. In an experiment described later (No. 7) electrodes were placed on opposite aspects of a thick region (the thigh). They were far apart in comparison with their size and a higher temperature was obtained under the peripheral than under the central portions.

### HEATING THE LOWER LIMBS

To introduce the lower extremities into the circuit a plate electrode may be placed in contact with the sole of one foot and a similar electrode in contact with the other sole. The electrodes are connected to the machine and the current is started and gradually increased.

Heat is felt first in the region of the ankles and afterwards in the legs. After some minutes there may be a perception of heat in the thighs, though usually the ankles become painfully hot before there is a sensation of heat in the thickest parts of the limbs. If the current is not strong enough to cause unbearable heat in the ankles there will be a perception of heat throughout the body, but several minutes have to elapse before general heating occurs. If, however, the ankles are excluded from the circuit (by removing the plate electrodes from the soles and placing a metal belt electrode around the lower part of each leg) the sensation of heat in the body as a whole will be felt sooner. The back of the knee will feel hotter than the front. The application of thermometers will show the rises of temperature that occur in the limbs and other parts of the body.

In an experiment of this kind the following rises were observed.

EXPERIMENT 6. Same subject as in Experiment 1. Semi-recumbent position with knees extended. Plate electrodes applied to soles. A current of 0·6 ampere was passed. After ten minutes there was a sensation of painful aching in the ankles. The plate electrodes were then replaced by belt electrodes around the lower parts of the legs. A current of 0·9 ampere was passed for twenty minutes. The temperatures obtained are noted in the columns below. The temperatures in the second column are those noted after ten minutes when the ankles became painful. The figures in the third and fourth columns are the temperatures noted after the stronger current has passed for fifteen and twenty minutes respectively.

| | | | | | Total Rise. |
|---|---|---|---|---|---|
| Front of ankle . . . . | 85·2 | 96·8 | — | — | 11·6° |
| Front of leg (about middle) . | 87·8 | 90·6 | 95·0 | 96·2 | 8·4° |
| Back of leg (about middle) . | 86·0 | 88·8 | 95·0 | 96·8 | 10·8° |
| Front of thigh (about middle) . | 89·4 | 89·6 | 90·6 | 90·6 | 1·2° |
| Perinæum . . . . . | 98·6 | 98·6 | 100·4 | 100·4 | 1·8° |
| Posterior fornix of vagina . | 97·8 | — | — | 99·3 | 1·5° |
| Mouth . . . . . | 96·2 | — | — | 99·2 | 3·0° |

In this experiment the part of the body in the circuit consisted of the lower limbs and that part of the pelvis between the hips. The lower limbs were heated by the current (joule heating) and the other parts of the body outside the circuit were heated by convection.

The different degrees of heating at various distances along the limb will be noted. A similar phenomenon was observed in the upper limb and the same explanation can be given. The lower limb, *like the upper, is a lengthy conductor with* a small cross-sectional area, *especially in the region of the* leg. But whereas the upper limb exhibits no great difference in its cross-sectional area at different levels, the reverse is the case in the lower limb. Just above the ankle the cross-sectional area is the smallest; in the region of the calf it is much wider and in the middle and upper parts of the thigh it is wider still. The differences are still more marked in the female figure. When the current passes along the limb it can attain a density in the ankle high enough to produce unbearable heat, while in the thigh the density is too low to produce more than a slight rise of temperature.

It will be noted that the temperature of the back of the leg rose a greater number of degrees (10·8) than the temperature of the front (8·4), in spite of the fact that the thermometers were at the same distance from the ankle. A similar phenomenon was observed in the forearm. Most of the posterior portion of the leg is occupied by muscle. Bone occupies much of the antero-internal portion. In the experiment the anterior thermometer was placed over the anterior border of the tibia. The more resistant bone and the less resistant muscle were grouped in *parallel* in relation to the direction of the current.

In regard to the question of deep heating, the same arguments as those already brought forward in the case of the upper extremity likewise favour the conclusion that the deep tissues of the *leg* are heated. There is also some experimental evidence on the living human subject. An experiment was conducted by Bierman and Tarbell.[1] A thermocouple was introduced into the calf muscles. Particulars are given below.

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[1] *Archives of Physical Therapy, X-ray, Radium,* November, 1934.

> Two electrodes were made to encircle the leg, one just above the ankle and the other just below the knee. The distance between the upper edge of the lower electrode and the lower edge of the upper electrode was 6 cm. (about 2·4 in.). A thermocouple needle was inserted midway between the electrodes into the muscles of the calf to a depth of 1 in. The current reached a maximum of 0·8 ampere. The temperature of the muscles rose from 35·2° C. (95·3° F.) to 42° C. (107° F.) The skin temperature midway between the electrodes rose from 31·6 C. (88·8° F.) to 38·4° C. (101·1° F.)

The writer is unaware of any similar experiment on the thigh. Theoretically, the bulk of this part and its large cross-sectional area are unfavourable for the production of more than slight rises of temperature in the deep regions of the thigh when it is included in the circuit in the way described in the experiment (No. 6). The slightness of the rise of the skin temperature of the thigh has already been noted.

The leg or thigh can be included in the circuit by placing the electrodes on their *opposite* aspects. When they have this situation the relation of the current to the limb is different from that which prevails when the electrodes are placed at the ends of the limb. The current passes *across*, rather than along, the limb, and if the electrodes cover a large area the conductor between them is short and broad, whereas it is long and narrow when they are at the ends of the limb.

Assume that electrodes of the same length are applied, first to opposite aspects of the leg, and afterwards to opposite aspects of the thigh. When they are applied to the *leg* the distance between them is short in comparison with their length. Consequently the outlying paths in the adjoining tissues grow rapidly longer as the distance from the electrodes increases. On the other hand, when they are applied to the *thigh*, the distance between them is greater, in comparison with their length ; therefore the outlying paths do not as rapidly grow longer when the distance from the electrodes increases. For these reasons it may be assumed that a smaller proportion of the current passes by the outlying paths when the electrodes are close together than when they are farther apart.

In order to ascertain whether there is any difference between the current-density under the peripheral and that under the central part of the electrode, when the latter are farther apart, an experiment like No. 5 (p. 111) was performed. It will be remembered that when the electrodes were placed on opposite aspects of the forearm they were close together in comparison with their length, and it was found that the current density was not lower under the *central* portion of the electrode than under the peripheral.

Experiment 7. Subject semi-recumbent. Each electrode measured 6·5 in. by 8·5 in. One was placed on the posterior aspect of the thigh with a pad, slightly larger, and soaked in salt solution between the metal and the skin. The other electrode was placed on the anterior aspect, directly opposite the first. It was separated from the skin by five small pads of equal size and thickness. They were quite separate from each other. Four were placed under the corners and the fifth under the centre of the electrode. The current reached a maximum of 0·8 ampere. The following rises of temperature were obtained under the central pad, also under a pad near the groin, and under a pad near the knee. The distance between the metal plate electrodes was 8·5 in. near the groin, and 7·5 in. near the knee.

| | Pad near groin. | Central Pad. | Pad near knee. |
|---|---|---|---|
| Before passage of current . . . . | 95·0 | 95·0 | 93·2 |
| After passage of current for 5 minutes . | 95·8 | 95·8 | 93·2 |
| After passage of current for 10 minutes . | 97·0 | 96·8 | 95·0 |
| After passage of current for 15 minutes . | 98·6 | 98·4 | 96·8 |
| After passage of current for 20 minutes . | 101·2 | 100·4 | 100·0 |
| Total rise . . . | 6·2 | 5·4 | 6·8 |

It will be observed that the temperature rose a smaller number of degrees under the *central*, than under the proximal or distal electrodes. It may be concluded, therefore, that the current attains a greater density under the peripheral than under the central portions of the electrodes when the latter are not close together. In the experiment on the forearm (No. 5) the distance between the electrodes was one-third to nearly one-half of their length. In the experiment on the thigh the distance between them was equal to or a little more than their length.

When the electrodes are placed on opposite aspects of the lower limb, the current, as is the case with the upper limb, encounters the tissues of different resistance *in series* rather than in parallel. The skin, however, is encountered in series *where it is in contact with the electrodes*, and in parallel *where it is uncovered by the electrodes* on the external path between them. The following experiment illustrates the different degrees to which the skin is heated where it lies in series and where it lies in parallel.

Experiment 8. Subject semi-recumbent. Each electrode measured 6·5 in. by 8·5 in. They were very slightly curved from side to side. One was placed on the anterior aspect and the other on the posterior aspect of the thigh. When they were in position the distance between the centre of each electrode through the thigh was about 8 in. The distance between their outer edges along the uncovered lateral aspect of the thigh was about 8·5 in. A current of 1·0 ampere was allowed to pass for twenty minutes. At the end of this time the following rises of temperature were observed.

| | |
|---|---|
| Front of thigh, under centre of electrode | 9·0° (from 93·2 to 102.2). |
| Back of thigh, under centre of electrode | 9·2° (from 91·4 to 100·6). |
| Uncovered side of thigh, between electrodes. | 2·0° (from 93·4 to 95·4). |

When the current passes *along* the lower limb between its ends it heats the tissues of the popliteal space to a higher degree than the bones of the knee because the highly impedant bone and the less impedant tissues of the popliteal space are grouped *in parallel*. But when the electrodes are placed on the anterior and posterior aspects of the knee the tissues of the popliteal space are heated to a lower degree than the bone because the tissues of different impedance are grouped *in series*. These facts are illustrated by the following experiments.

Experiment 9. The lower limb was fully extended. A belt electrode was placed around the upper part of the thigh, and another around the leg just above the ankle. A current of 0·9 ampere was passed for 15 minutes. The temperature over the patella rose 3·6° (from 80·6 to 84·2). That of the skin of the popliteal space rose 12·6° (from 86 to 98·6).

Experiment 10. One electrode was placed on the patella and the other on the skin of the popliteal space. A current of 0·5 ampere was passed for 15 minutes. The temperature of the skin over the patella rose 20·6° (from 80·6 to 101·2). That of the skin of the popliteal space rose 18° (from 86 to 104).

In regions where bone has a deep situation and is surrounded by less resistant muscle, as is the case with the shaft of the femur, it is doubtful whether the current can heat the bone, whatever the position of the electrodes. When the electrodes are placed on opposite aspects of the thigh the greater proportion of the current will pass along the muscles, and it seems improbable that enough will pass along the bone to raise its temperature. The same will be the case when the electrodes are placed *at opposite ends* of the thigh. In the upper arm the shaft of the humerus is surrounded by muscle, as is the case with the femur. But electrodes covering the anterior and posterior aspects of the upper arm, or its lateral aspects, are relatively close together. This fact, and the smallness of the size of the upper arm in comparison with the thigh, enable the current to obtain a higher density in the region of the humerus than in the vicinity of the femur. It seems probable, therefore, that the shaft of the *humerus* can be heated by the diathermic current, though to a lower degree than the surrounding muscles.

## HEATING THE TRUNK

The trunk can be placed in circuit by applying a plate electrode to the anterior aspect and another to the posterior aspect. The anterior and posterior aspects, either of the trunk as a whole, or of the thorax or abdomen, are seldom covered in their entirety by the electrodes, except for the production of high degrees of *general* diathermy in treatment by so-called "therapeutic pyrexia." Assume, now, that a plate electrode measuring 5 in. by 7 in. is placed on the abdomen and another of the same size on the back, directly opposite the first electrode. After they are connected to the diathermic machine and the current gradually increased, the subject will perceive a sensation of heat under the electrodes. Gradually it becomes more intense. But in other parts of the body there is usually no sensation of heat, even after the expiration of fifteen or twenty minutes. If there should be a sensation of warmth elsewhere it never approaches the degree which is felt elsewhere when the limbs, especially the upper, are in the circuit. Thermometers will indicate a considerable rise of temperature of the skin in contact with the electrodes. The skin on the exterior, between the electrodes where it is uncovered by them, will show a slight rise. A thermometer under the tongue may indicate a rise; if so, the rise will be very slight.

If the experiment is performed on a female patient a thermometer can be introduced into the vagina with its bulb in the posterior fornix. In this position the bulb will be in the deepest part of the interior of the pelvic cavity. It will show *no* rise of temperature for several minutes. Even at the end of twenty minutes it may show no rise, or, at the most, a rise of no more than a fraction of a degree, in spite of the fact that the skin may have been heated to the limit of toleration.

In some experiments of this kind the following figures were observed.[1]

EXPERIMENT 11. Female patient in recumbent position. The electrodes measured 5 in. by 7 in. One was placed on the lower abdominal wall with its lower edge just over the symphysis pubis. The other electrode was placed directly behind the first. A current of 1·4 amperes was passed for twenty minutes. The following rises of temperature were noted:—

| | |
|---|---|
| Anterior surface of abdomen under centre of electrodes. | Rise of 10·2° (from 92·4 to 102·6). |
| Under centre of posterior electrode. | Rise of 17·6° (from 86·6 to 104·2). |
| Uncovered skin midway between electrodes. | Rise of 1·0° (from 94 to 95). |
| Posterior fornix of vagina . | No rise (temperature remained at 97·8). |
| Under the tongue . . | No rise (temperature remained at 96·2). |

The next experiment was conducted on another female patient who had a normal oral temperature; in the other it was subnormal. The electrodes had the same size and situation, and a current of the same strength was passed for the same time. The following temperatures were noted at the end of the experiment.

EXPERIMENT 12.

| | |
|---|---|
| Uncovered skin, midway between electrodes. | Rise of 3·6° (from 92·2 to 95·8). |
| Perinæum . . . . | Rise of 3·6° (from 92·8 to 96·4). |

---

[1] In these experiments the patients suffered from no disease of the pelvic organs and no organic disease of other parts.

| | |
|---|---|
| Posterior fornix of vagina . | No rise (temperature remained at 98·8). |
| Under the tongue . . . | No rise (temperature remained at 98·2). |

The next experiment was conducted on another patient in the same manner as in the two previous experiments, but the current was allowed to pass for thirty-five minutes. The following rises of temperature were noted at the end of the experiment.

EXPERIMENT 13.

| | |
|---|---|
| Posterior fornix of vagina . | Rise of 0·2° (from 98·6 to 98·8). |
| Under the tongue . . . | Rise of 0·2° (from 98·4 to 98·6). |

In the three previous experiments the circuit in the patient consisted of the body wall and the viscera within the abdomen. The viscera within the thoracic cavity, being far from the region between the electrodes, may therefore be regarded as outside the circuit.

The highest rises of temperature were obtained in the skin underlying the electrodes. The skin on the lateral aspect, between the electrodes, where it was uncovered by them, showed a slight rise of temperature. But in the depths of the pelvic cavity there was no rise, even though twenty minutes had elapsed, and there was only a very slight rise after the current had passed for thirty-five minutes.

The skin under the electrodes was heated directly by the current (joule heating). In this situation the current passed transversely across the skin and heated it several degrees. On the lateral aspect the current passed longitudinally in the skin and heated it only slightly. In this situation the skin formed one of the conductors grouped *in parallel*—the other conductors grouped *in parallel* were the superficial fascia, the underlying muscles and the iliac bones. The conductors grouped *in series* were the superficial fascia and muscles under the anterior electrode, and the superficial fascia, muscles and bones under the posterior electrode. The viscera may be regarded as grouped partly in series and partly in parallel.

The slight rise of temperature that was observed in the depths of the pelvic cavity in Experiment 13 might have been due to *direct* (joule) heating of the viscera. But it might have been due to convection of heat from the hot body wall. During the time occupied by the experiment there was a continuous stream of blood through the heated body wall, and it is likely that the blood itself and eventually the entire quantity of circulating fluid was heated. It will be observed that there was a rise of the *oral* as well as the intrapelvic temperature at the end of the experiment. This explanation of the rise of temperature in the interior of the pelvic cavity is, perhaps, the correct one, because a rise of temperature in this region has been observed by the writer after the upper limbs had been subjected to diathermy; at the same time the oral temperature rose. Thus, in one experiment, a current of 1 ampere was passed along the upper extremities (the wrists being excluded); after twenty minutes the temperature of the posterior fornix rose 0·4° (from 99·2 to 99·6) and that of the mouth rose the same amount (from 98·8 to 99·2).

Whatever the explanation may be of the rise, or its absence, it must be realised that the conditions are all unfavourable for the production of a rise of temperature in the depths of the body cavity, whether pelvic, abdominal or thoracic. There are three main reasons.

In the first place, the trunk, unlike the limbs, is bulky in all three dimensions, and the elctrodes can cover only a small part of the surface when local treatment is given. Consequently there are outlying paths for the current all round the direct paths. When electrodes of suitable width are placed on opposite aspects of a limb it will be recalled that there are outlying paths for the current only in the tissues proximal and distal to the electrodes (Fig. 67). In the case of the trunk, however, there are paths in the viscera above, below and on each side of the direct paths. Further, the outlying paths are not a great deal longer than the direct paths, seeing that the electrodes are some distance apart.

There are two other reasons why the current is unable to produce a rise, or more than a slight rise, in the depths of the body cavity. Not only is the resistance (impedance) of the viscera low, but they have an abundant blood supply.

Their low resistance does not favour the production of high degrees of heat, and the abundant quantity of blood that streams through them favours the removal of heat by convection.

It may be concluded then that very little heat is generated in the viscera and most of it, if not all, is carried away by the circulation. The reverse is the case when the limbs, in their entire length, are in the circuit. Much heat is produced. Although enough is carried away to enable the temperature of the rest of the body to rise, enough remains to cause a rise of temperature of the parts in the circuit.

It is possible to introduce a thermometric instrument into the abdominal cavity of the intact human body by way of *the œsophagus and stomach. If this is done, electrodes can be applied to the exterior of the trunk and placed in the circuit of a diathermic current. In this way the influence of the current on the gastric temperature can be studied.*

An experiment of this kind was conducted by Bierman and Tarbell (*loc cit.*, p. 114).

A tube containing a thermocouple was swallowed by the subject of the experiment. Its position in the stomach was located by X-rays. The subject was placed in a prone position. An oval plate electrode measuring 12·5 cm. by 18·7 cm. was placed on the anterior aspect of the abdomen. Another oval electrode, measuring 15 cm. by 22·5 cm., was placed on the posterior aspect. The current was gradually increased to a maximum of 3·2 amperes. During twenty-eight minutes the stomach temperature rose from 36·9° to 40·5° C. (*i.e.*, from 98·4° to 104·9° F.). The general temperature showed a rise of 0·2° C., *i.e.*, 0·3° F.

Bierman and Tarbell showed that the rises of temperature were not brought about by any direct action of the current on the thermocouple.

The rise of temperature within the stomach calls for some comment because little or no rise was observed in the interior of the pelvis in the experiments previously described, in which the electrodes were placed on the lower parts of the abdomen and back. It must be remembered that a portion of the stomach comes in contact with the inner aspect of the abdominal wall so that an electrode on the skin will be close to the anterior gastric wall. Where the stomach and abdominal wall are in contact the current can attain a much higher density than in the depths of the abdomen. Further, the abdominal wall can be heated many degrees and it is likely that the part of the stomach in contact derives heat from it by conduction. In the same way it is probable that other viscera can be heated to a slight depth below their surface where they make contact with the heated abdominal wall. But their temperature is likely to sink rapidly to their normal value as the distance below the abdominal wall increases.

In the following experiment no rise of temperature was produced in the region of the kidney.

EXPERIMENT 14. The subject of this experiment was an adult patient who had previously undergone an operation for pyonephrosis. Healing was incomplete and a discharging sinus remained. A thermometer was introduced into the sinus, its bulb being in the region formerly occupied by the affected kidney. One electrode was placed on the back, its position corresponding to the surface marking of the kidney. The other electrode was applied to the anterior abdominal wall. The current was gradually increased, and eventually the patient said that the heat was becoming painful. The thermometer showed no rise of temperature throughout the experiment.

### HEATING THE PELVIC ORGANS

It is easy to demonstrate the heating of some of the pelvic organs when one of the electrodes is placed within one of the channels that lead into the pelvic cavity. If a suitable electrode is placed in the vagina, urethra or rectum, the circuit being completed by means of a metal belt around the exterior of the trunk, the current can heat the parts in contact with the internal electrode and those for some distance around it.

### HEATING THE HEAD

The mouth and its contents can be subjected to diathermy by placing an electrode on each cheek. Thermometers in different parts of the oral cavity will indicate the temperatures produced by the current.

Experiment 15. In this experiment one thermometer was placed on the exterior of one cheek, under the electrode; another was placed on the buccal aspect of the same cheek; a third was placed on the buccal aspect of the lower lip opposite the central incisor teeth; a fourth was placed under the tongue. After fifteen minutes the following rises of temperature were noted:—

| | |
|---|---|
| Exterior of cheek . . . | 11° (from 90 to 101). |
| Interior of cheek . . . | 7·2° (from 95·8 to 103). |
| Behind lower lip . . . | 2·8° (from 95·6 to 98·4). |
| Under tongue . . . . | 2·4° (from 96·2 to 98·6). |

If electrodes are placed on the frontal and occipital aspects of the head, or on its lateral aspects, it is theoretically possible that the cerebral contents may be heated. The skull wall and the overlying scalp under the electrodes will attain the highest temperature by reason of their resistance (impedance) and their close proximity to the electrodes. Some of the current will pass along the uncovered part of the scalp between the electrodes, and some will pass along the subarachnoid fluid round the brain. For these reasons one cannot expect more than a slight rise of temperature in the brain.

An experiment was conducted on the head of a dog by Cloetta and Waser (*Journal fur Experimentale Pathologie und Pharmakologie*, June 25th, 1914). A thermometer with its bulb in one of the lateral ventricles indicated a rise of 1° C. after the current had been passing for ten minutes by way of electrodes on the exterior of the head.

## SUMMARY AND CONCLUSIONS

When the current passes *along* the upper limb it can attain a high density by reason of the small cross-sectional area of the part, and heat it several degrees. There is evidence that the less resistant muscles are heated to a higher degree than the more resistant bones because they are grouped *in parallel*. When the current passes *across* the limb, in situations like the wrist and elbow, where most of the posterior portion is occupied by bone, this tissue attains a higher temperature than the less resistant soft tissues of the anterior portion because the two resistances are grouped *in series*. In the upper arm the shaft of the humerus is grouped *in parallel*, both when the current passes along the limb and when it passes across it. The conditions, therefore, are unfavourable for heating it more than a slight degree.

When the current passes along the lower limb it can attain a high density in the knee and the parts below, and heat them many degrees—the muscles and soft parts more than the bones. The bones, however, are likely to attain a higher temperature, more particularly in the region of the knee and ankle, when the current passes *transversely*. In the thigh the current cannot attain as high a density as in the leg when the current passes *longitudinally*. The conditions are unfavourable for heating the shaft of the femur, both when the current passes longitudinally and when it passes transversely.

When the current passes across the trunk it can heat the body wall and probably those parts of the viscera that are in contact with the anterior abdominal wall or with the walls of the thorax. It is very unlikely that the more deeply placed viscera are heated *directly* by the current (joule heating) when both electrodes are placed on the exterior, and in the writer's opinion the interior of organs like the liver, kidneys, heart, etc., cannot be *directly* heated by the diathermic current. On the other hand, the pelvic organs can be heated *directly*, some of them several degrees, when one of the electrodes is inserted *per rectum* or *per vaginam.*

In the case of the head the current is able to heat the parts within the buccal cavity. In regard to the brain, its enclosure within the cranium is unfavourable for the production of heat in its internal parts. It is likely that the skull can be heated, and if so it may be concluded that some will be communicated to the meninges and the surface of the brain.

When electrodes are placed on the exterior of the chest or abdomen the internal organs that are unlikely to be heated by the current itself may nevertheless be heated *indirectly* through the agency of the blood, *i.e.*, by convection. The heat is not conveyed directly from the body wall to the organs in the body cavity. It is distributed in the body as a whole and the organs receive a share of it. This indirect conveyance of heat from the body wall cannot be expected to procure more than a slow and trifling rise of temperature in other parts. A quicker rise to a higher degree can be obtained when the limbs are placed in the circuit.

Heating by convection is *general*, rather than *local*, and it gradually produces a rise of temperature of the whole body. When this occurs it is customary to say that *general diathermy* has been produced. It must be remembered, however, that the heat is not generated in the body as a whole, but only in some parts of it, and conveyed therefrom to the remaining parts.

It must be admitted that much additional information must be obtained before it can be decided whether inaccessible organs, such as the brain, heart, liver, etc., can, or cannot, be locally heated by the diathermic current.

### IMPEDANCE OF DIFFERENT TISSUES

When a region of the body is on the path of a diathermic current its impedance is one of the factors that influence the degree to which it is heated. Since the tissues composing a region present different degrees of impedance it is evident that the current will not heat all the tissues to the same degree, even if it attained the same density in each.

The following table shows the relative degrees of impedance of various tissues, that of 0·5 per cent. salt solution at 18° C. being taken as unity. The figures were determined by Wildermuth.

| | |
|---|---|
| Adipose tissue | 19·4 |
| Brain | 5·5–6·8 |
| Lung | 3·5–4·0 |
| Liver | 2·8–3·3 |
| Skin | 2·5–3·0 |
| Muscle | 1·2–1·5 |
| Blood | A trifle higher than 1·0.[1] |

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[1] Figures representing the relative impedance of bone are not given by Wildermuth. H. J. Taylor made an experiment in order to ascertain the degree to which a preparation of bone could be heated in comparison with agar made up with normal saline. A quartz vessel was filled with the agar. One-half of the agar was cut out and its place taken by ground-up cancellous bone. The diathermic current traversed the two conductors *in series*. The temperature of the agar block rose 1·2° C. That of the bone rose 7° C. This experiment showed that the bone was approximately six times as resistant as the agar.

The high impedance of adipose tissue and the low impedance of skin should be noted. In the case of the galvanic current the skin provides a higher resistance than any other tissue. The high degree with which fat impedes the oscillation of the diathermic current is one of the factors that inhibit the production of heat in the deep parts of the body. Fat is present in the superficial fascia of almost all regions, and in some parts, particularly the trunk, it may be present in considerable thickness. When the electrodes are placed on opposite aspects of a limb, or the trunk, the current will attain almost its highest density in the superficial fascia where the highly impedant fat is present. Consequently there are two factors that cause the diathermic current to produce the highest temperatures in the external portions of the body. On the other hand, the low impedance of muscle and the diminution of the current density (when the electrodes have the positions above stated) are factors unfavourable for the production of high degrees of heat in the internal parts.

### INFLUENCE OF THE BLOOD AND ITS CIRCULATION

By reason of its continuous onward movement the blood plays an important part in influencing the temperature to which the body can be heated by the diathermic current.

In the first place it impedes the efforts of the current to create a local rise of temperature. It acts in this way because it streams continuously through the region on the path of the current and removes heat from it. It plays, in fact, the part of a " cooling " stream.

Secondly, the circulation is instrumental in causing, or tending to cause, a rise of temperature in parts away from those that are being subjected to the action of the current. It can do so because the heat removed by the blood is distributed in other parts of the body. In these parts the circulation has the action of a " heating " stream.

Apart from the fact that it circulates, the blood has a passive influence on the tissue-heating power of the diathermic current. Its impedance, as already stated, is low—lower, in fact, than that of any solid organ. The greater the quantity of blood the lower the resistance of the organ containing it, and the lower the power of the current to heat the solid tissues through which the blood flows.

Imagine that an organ, deprived of its blood, is placed on the path of a diathermic current and its temperature raised until it reaches a constant value. If now the organ is filled with blood its resistance will diminish, and if the current is maintained at the same value the temperature of the organ will fall. If fresh supplies of blood now are made to pass continuously through the organ its temperature will fall still more in spite of the fact that the resistance and the rate of production of the heat remain the same. The additional fall will be due to the removal of heat from the organ by the blood.

If only small quantities of blood pass through the organ the loss of heat will be correspondingly small and the temperature will not fall many degrees. On the other hand, if large quantities pass through in the same time the loss of heat will be great ; in fact, heat loss may be equal to heat gain. In this case the temperature of the organ will fall to the value it exhibited before it was subjected to diathermy.[1]

In the human subject the large amount of blood that streams through the viscera must remove a large proportion of the heat generated in them by the diathermic current. When it is remembered that the current is unable to generate much heat in the abdominal viscera by reason of their low impedance it is doubtful whether the temperature can be made to rise in the deeper parts of the body cavity where the density of the current is at its lowest value.

The case is different when the limbs are included in the circuit and the current passes longitudinally. The tissues that comprise the largest portion of a limb, viz., muscle and bone, are less vascular than the viscera, and the blood removes a small proportion of the heat generated within them by the current. It will be remembered that the current can attain a high density in the upper limbs and the legs. As the resistance of these parts is high, by reason of their length and their small cross-sectional area, the current can produce heat at a rate faster than that at which it is carried away. In the limbs, therefore, the circulation does not impede the rise of temperature to the extent that it does in the trunk.

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[1] The thorax of a dog was subjected to diathermy and the temperature of a lung rose only 0·4 above that of the rectum. After the pulmonary artery had been occluded the temperature of the lung which it supplied rose much higher. (Binger and Christie, "General and Local Heat Developed in Living Body by Passage of High Frequency Current." *Proc. Soc. Exper. Biol. and Med.* 24 : 677, April, 1927.)

The action of the circulation in removing heat is aided by another factor which comes into play as soon as the temperature of the blood begins to rise. Even if the rise is slight the viscosity of the blood diminishes. A reduction of its viscosity enables the blood to pass more easily along the minute vessels where ordinarily it encounters much frictional resistance. Consequently its movement is accelerated, and it is enabled thereby to remove heat at a more rapid rate.

There is also a biological phenomenon which occurs when tissues are heated. It is vasodilatation. It has a two-fold effect. In the first place the additional quantity of blood lowers the resistance of the part and thereby diminishes the amount of heat produced by the current. Secondly, it allows a greater quantity of blood to pass through the part. As a result the heat is lost at a faster rate.

The additional loss of heat in consequence of vasodilatation and decreased viscosity of the blood will occur, whatever region of the body is subjected to diathermy. But it will be greater in highly vascular parts like the viscera than in less vascular parts such as the muscles and bones.

### Heating the Blood by the Diathermic Current

The *loss* of heat from regions subjected to diathermy, through the agency of the circulation, has already been considered. There now remains for study the subject of the *gain* of heat by the blood, the convection of the heat to other parts of the body, and the temperature to which these parts may be raised.

During its passage through the parts that are being subjected to diathermy the blood may be heated in the same way as the tissues through which it circulates, *i.e.*, by the *overcoming of its resistance (joule heating).* This is *direct* heating. It can also be heated by conduction. In this way it receives heat from the solid tissues around it. This may be called *indirect* heating. Direct heating is probably less effective because the blood that enters an organ or region soon leaves it and is exposed for only a short time to the action of the current. On the other hand, the solid tissues are under the influence of the current the whole time, and when the temperature rises some of the heat will be conducted to the blood.

The degree to which the blood can be heated, either directly or indirectly, depends on the quantity that passes through the region. If the quantity is large, the heat that passes to it from the tissues cannot raise it to the temperature that it would produce if the quantity were small. Further, a current of the same density cannot heat a large quantity of blood to the same temperature as a small quantity. For these reasons the blood that leaves a vascular region cannot reach the same temperature as that leaving a less vascular part. Thus if a region of the abdomen is subjected to diathermy the blood in the portal vein cannot be expected to reach a temperature as high as that in the brachial vein when the upper limb is subjected to diathermy.

The degree to which the blood is heated during its passage through a region that is being subjected to diathermy is important because it determines the degree to which the other parts of the body are heated. As already stated, the heat received by the blood in its passage through a locally heated region passes into the general circulation and raises, or tends to raise, the temperature of the blood as a whole. When its temperature rises there will be a passage of heat, *from* the blood, *to* the solid tissues, and the temperature of the body as a whole may be elevated.

In order to produce a rise of temperature in regions other than those under the influence of the current it is necessary, not only to produce a high degree of local diathermy but also to procure it throughout a large mass of tissue. If a region of the trunk is subjected to diathermy the mass of tissue is large but only a low degree of heat can be produced in it, except in the *body wall*, which, however, constitutes only a small proportion of the mass. Consequently a trifling rise of the general temperature is all that can be expected when a region of the chest or abdomen is subjected to diathermy. On the other hand, a higher rise can be obtained when the upper limbs are subjected to diathermy because they constitute a large mass of tissue and can be heated a number of degrees.

The slightness of the rise of the oral temperature after a region of the abdomen had been subjected to diathermy was indicated in Experiment 13 (p. 120). In Experiments 11 and 12 the oral temperature did not rise at all. On the other hand, the higher rises that were obtained in different parts of the body after the upper limbs had been subjected to diathermy are indicated below.

Experiment 16. The subject of this experiment was seated, and the arms and knees were semi-flexed. A cylindrical electrode was grasped in each hand. A current of 0·4 ampere was passed for twenty minutes. The heat was insufficient to cause discomfort.

The following rises of temperature were noted in the parts *in the circuit* :—

| | |
|---|---|
| Front of wrist | 6·0° (from 94 to 100). |
| Front of elbow | 4·0° (from 95 to 99). |
| Axilla | 2·4° (from 98·8 to 101·2). |

The following rises were noted elsewhere :—

| | |
|---|---|
| Mouth | 2·6° (from 97·6 to 100·2). |
| Groin | 1·2° (from 98·8 to 100). |
| Popliteal space | 3·0° (from 98 to 101). |
| Between first and second toes | No rise. |

### INFLUENCE OF THE POSTURE OF THE LIMB

When joints like the wrist, elbow and knee are in a position of extension, and the current is passing longitudinally, a higher temperature is reached on the flexor than on the extensor aspect. This has already been observed. When the joints are in a position of flexion the temperature becomes still higher on the flexor aspect. This was demonstrated in the following experiments.

Experiments 17 and 18. A current of 0·5 ampere was passed along the upper limbs by way of rod electrodes grasped in the hands;

the elbows were fully extended. After ten minutes the following rises of temperature were noted :—

| | | |
|---|---|---|
| Front of elbow . . . . | 6·5° | (from 93·5 to 100). |
| Back of elbow (by side of olecranon) | 5·0° | (from 90 to 95). |

On the following day the experiment was repeated. The same strength of current was passed for the same time, but the elbows were flexed to a right angle. The following rises of temperature were noted :—

| | | |
|---|---|---|
| Front of elbow . . . . | 9·2° | (from 93 to 102·2). |
| Back of elbow (by side of olecranon) | 3·4° | (from 88 to 91·4). |

In these experiments the temperature rose a greater number of degrees on the *front* of the elbow than on the back, because the posterior portion is largely occupied by bone, whereas the anterior portion is occupied by soft tissues of lower impedance. When the elbow is flexed, the path for the current along the anterior portion of the limb is less impedant than the posterior, because the biceps and brachialis anticus, being contracted, are shorter and thicker, and therefore offer less impedance than when they are extended. Consequently a larger proportion of the current will pass along the anticubital fossa and the flexor region of the upper arm. This is the probable reason why a higher temperature is obtained on the front of the *flexed* elbow than on the front of the *extended* elbow.

It is easy to demonstrate the reduction of the impedance of the arm when it is flexed. A rod electrode is held in each hand and connected to a diathermic machine. The position of the amperemeter needle is noted when the current is passing and the arms *extended*. The needle will indicate a slight increase of the current when the arms are *flexed*. If the arms are again extended the current will diminish to its former value.

The following experiment illustrates the difference in the distribution of the temperature in the *flexed*, as compared with the extended knee after the current has passed along the lower limbs. In the extended position there was a higher rise of temperature, as would have been expected, on the *posterior* aspect of the knee than on the anterior aspect. In the flexed position the difference was markedly accentuated : there was a trifling rise on the anterior aspect and a high rise on the posterior aspect.

EXPERIMENT 19. The subject sat on a chair, one lower limb being supported in a position of extension at the knee, the other being flexed to a right angle with the foot resting on a cushion. A belt electrode was placed around each limb just above the ankle and connected to a diathermic machine. The subject had short thickly covered lower limbs. The following rises of temperature were observed :—

*Extended Knee*

| | |
|---|---|
| Anterior . . . | Rise of 7·6° (from 84·6 to 92·2). |
| Posterior . . . | Rise of 10·2° (from 85·0 to 95·2). |

*Flexed Knee*

| | |
|---|---|
| Anterior . . . | Rise of 3·6° (from 86·8 to 90·4). |
| Posterior . . . | Rise of 15·0° (from 92·6 to 107·6). |

### INFLUENCE OF THE SHAPE AND POSITION OF THE ELECTRODES

The shape of the electrodes and their position in relation to each other are other factors which influence the degree to which the tissues between them are heated by the diathermic current. They are controllable factors and of considerable importance in the practice of diathermic treatment.

In those experiments in which the current was directed across the trunk or a limb the electrodes were flat, or nearly flat, and they were placed on opposite aspects of the part, one being directly behind the other. In these positions they were in approximately parallel planes and their corresponding parts were more or less equidistant.

If the electrodes are opposite each other but not parallel the paths between their corresponding parts will be of unequal length. Consequently they will not have the same impedance. If there is a marked difference in length between the short and the long paths there will be a corresponding difference between their impedance. The current, therefore, will attain a greater density in the tissues forming the short paths and heat them to a higher temperature than those which form the long paths. If the electrodes are placed very obliquely in relation to one another so that two of the corresponding edges are close together, and the other two relatively far apart, almost all the current will pass through the tissues where the edges are close together. This concentration of current in the tissues in the vicinity of the closely opposed edges of the electrodes is spoken of as the "edge-effect." The current may heat to a high degree, or even burn, the tissues where the edges are close together, even though the tissues in the region where the electrodes are far apart are heated scarcely at all.

The edge-effect occurs if plate electrodes are placed on the sole and dorsum of the foot. They will be much closer together at the outer than at the inner edges; they will likewise be nearer at their anterior than at their posterior edges. If the current heats the outer border and anterior portion of the foot to the limit of toleration the inner border and posterior portion will only slightly be warmed. But if the last-mentioned parts are strongly heated the others will be damaged from overheating.

If the electrodes are markedly curved so that their edges are much closer together than their centres the tissues between them will be heated very unevenly. An edge-effect, brought about by the use of electrodes of this kind, is witnessed when curved electrodes are placed on opposite aspects of parts like the knee, thigh, upper arm, etc., which are round, rather than flat, in cross section. If their edges are much closer together than their central portions the heat will be restricted almost wholly to the tissues in the vicinity of the closely opposed edges, while the tissues between the central portions will not perceptibly be heated.

Instead of placing plate electrodes on opposite aspects of a limb a couple of belt electrodes may be made to encircle it some distance apart. Unless these "cuff electrodes," as they are sometimes called, are placed a considerable distance apart it is unlikely that the deep parts between them will be heated. If they are close together the heat will be restricted to the superficial tissues where they are uncovered, between the closely opposed edges. In other words, a "circular edge-effect" will be produced; at the same time the skin under the most distant edges will be heated scarcely at all.

If plate electrodes are placed close together on the same aspect of a part of the body the edge-effect will again occur. It was demonstrated in the following experiment.

EXPERIMENT 20. Two electrodes were placed on the extensor aspect of the forearm. They were 3 in. in diameter and their nearest edges were 1 in. apart. Before the diathermy was applied the temperature under each electrode was 92°. After the application the temperature under the centre of each electrode had risen 8°. Where the edges were closest together the skin showed a rise of temperature amounting to 21°. Its actual value was 113°. Erythema was marked in the region where the electrodes were closest together. It was not apparent where the electrodes were far apart.

If a cuff electrode is placed around the calf and a plate electrode applied to the sole the temperature will be very uneven in the different parts. The ankle will attain the highest temperature. On the other hand, the front of the foot will show no apparent rise. These differences can strikingly be demonstrated by placing the electrodes in the positions above stated on a limb which is cold and blue. The skin gradually loses its blue appearance and its chilly feel. It acquires a vivid red colour and becomes quite hot. These changes in temperature and appearance are only seen, however, in the ankle and heel. The front part of the foot remains cold and blue.

When the electrodes have the position just stated the paths between them differ in length. Those that pass through the anterior portion of the foot are longer than those that pass through the ankle, and they offer more impedance to the current. But the difference is not great enough to account for the high degree of heat in the ankle and the apparent absence of heat in the front of the foot. If the diathermic current had distributed itself in the paths of different length like a *galvanic* current, there would have been, at any rate, an appreciable degree of warmth in the front of the foot. But the diathermic current, oscillating with high frequency, " concentrates itself " in the less impedant paths between the electrodes. The edge-effect, already described, likewise exemplifies the disproportional " concentration " of the diathermic current in the shortest paths between the electrodes.

### LOSS OF HEAT FROM PARTS SUBJECTED TO DIATHERMY

When a region of the body is in the circuit of a diathermic current its temperature will rise, provided the gain of heat is not equalled by its loss. It must be realised that there are a number of ways in which the heat can be removed from the part in which it is generated.

One of them—and the most important—has already been considered, viz., loss by *convection*, through the agency of the blood stream.

Another way in which heat can be removed is by *conduction*. Heat can pass by this process from tissues under the influence of the current to those which lie adjacent and beyond.

A third way in which heat can be removed is by *radiation* from the surface. Heat removed in this way is actually lost from the body, whereas that removed by conduction and convection is retained within the body. A considerable amount of heat can be lost by radiation if the skin is uncovered or covered only by the electrodes.

A fourth way in which the heat generated in the body by the diathermic current can be lost should be borne in mind. It is by convection through the agency of the *air*. Air currents normally pass from the warm skin and tend to cool it. When the skin is heated the air currents are increased and they remove heat more rapidly, especially if the skin is uncovered.

Since there are all the above-mentioned ways in which heat can be lost from the region on the path of the diathermic current it is evident that the temperature will be the resultant of heat-production and heat-loss. In the human subject it is not possible to prevent loss of heat by convection and conduction. But loss by radiation and by air-convection can be lessened or prevented by enclosing the part in flannel or blankets, and if this precaution is taken a higher temperature can be obtained.

## CONDUCTION OF THE DIATHERMIC CURRENT BY THE BODY

### Impedance of the Body

The body offers less opposition to the passage of oscillatory currents than to the passage of the galvanic current, and if the frequency of the oscillation is high the opposition (impedance) is still less. When a cylindrical electrode was held in each hand it was shown by Dowse and Iredell[1] that the impedance of the portion of the body between the electrodes varied between 450 and 650 ohms for the diathermic current. From deltoid to deltoid the impedance was 45 ohms. For the galvanic current the resistance from hand to hand (the hands immersed in saline) was found by Weiss to vary between 1,300 and 1,500 ohms.

## Path of Diathermic Current in Tissues

When the horny layer of the epidermis is perfectly dry it prevents the passage of a galvanic current. But it does not prevent the passage of an oscillatory current like the diathermic. It behaves as a dielectric and a displacement current occurs in it. If a pair of plate electrodes make good contact with the dry skin and are connected to a source of diathermic current the needle of the amperemeter will move along the scale when the oscillator and resonator are coupled. It will move even if a thin layer of glass or ebonite is interposed between the metal and the skin. The horny layer and the glass or ebonite act as a dielectric of a condenser, and the metal plate and soft tissues under the horny layer act as the armatures.

The cell of the stratum germinativum and those of other tissues can also act as condensers. The cell membrane constitutes an imperfect dielectric, while the protoplasm and extracellular fluid act as the armatures. The current is provided with two paths. One is in the extracellular fluid. The other is across the cell, a displacement current occurring in the cell membrane. When the oscillation has the frequency of about 1,000,000 cycles per second—the average frequency of a diathermic current—a larger proportion of the current will oscillate in the extracellular fluid. When the frequency is raised to 10,000,000 cycles per second the reverse is the case ; and when the frequency is 50,000,000 or more cycles per second the oscillation occurs almost entirely in the cell.

Experimenting with portions of the bloodless liver of a rabbit, Philippson[1] found an impedance of 1,950 ohms for a current oscillating with a frequency of 500 cycles per second. With a frequency of 50,000 cycles the impedance was 1,025 ohms, and with a frequency of 5,000,000 the impedance was 245 ohms.

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[1] *Archives of Radiology and Electrotherapy* (now *British Journal of Radiology*), July, 1920.

*According to these findings the conductivity of the tissue increased when the frequency of the oscillation was raised.* A greater proportion of the current oscillates in the cells, and as the extracellular fluid is much smaller in amount than the volume of the cells the path through the liver by way of the cells must offer less impedance than the path *between* them.

### EXPERIMENTS ON ARTIFICIAL HOMOGENEOUS CONDUCTORS

The uneven distribution of temperature due to curvature of the electrodes or to their oblique posture in relation to each other can be shown by experiments on conductors made of gelatin or fango. Thermometers can be introduced and the internal temperature measured in different situations. Experiments of this kind, while giving no guide as to the temperatures that can be obtained in the living body, are nevertheless of use because they demonstrate the distribution of the temperature in conductors of various forms when the electrodes differ in size and in their relative positions.

The following experiments were made by Professor Lloyd Hopwood. The conductors were made by dissolving gelatin in 0·5 per cent. salt solution, each litre of the solution containing ½ lb. of gelatin. The solution was allowed to set in glass moulds of various shapes. The current from a triode valve diathermic machine was passed through the conductors by way of metal plate electrodes. The frequency of oscillation of the current was 1,000,000 cycles per second, and its strength was measured by a Weston radio-frequency amperemeter. Alcohol thermometers were placed in different parts of the gelatin. They were read at intervals. Strong currents were used and applied for short times only in order to avoid, as far as possible, the errors that would have arisen from conduction of heat from parts at higher temperatures to others at lower temperatures.

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[1] Académie Royale de Belgique: *Bulletin de la Classe des Sciences*; Séance du 4 Juin, 1921.

In Fig. 69 the shapes of the conductors are indicated at (*a*), (*b*), (*c*), (*d*) and (*e*). The thermometers were placed

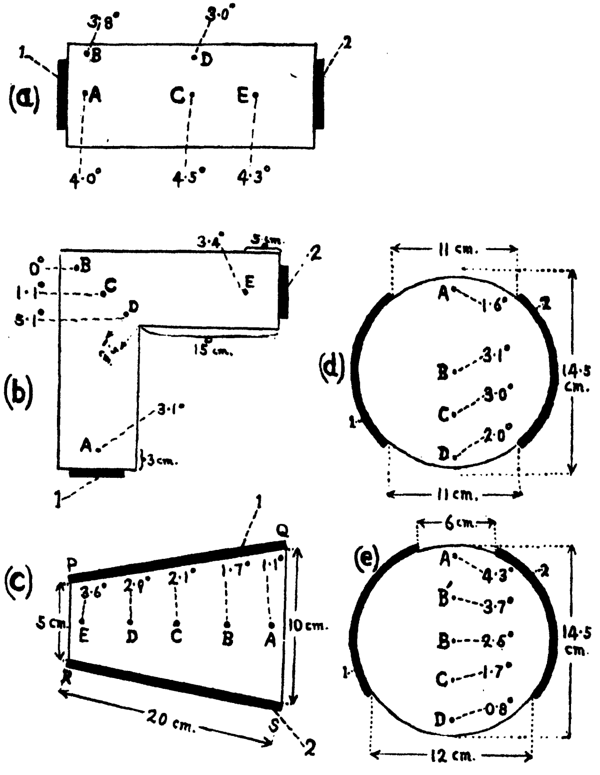


FIG. 69.—To illustrate the Distribution of Diathermic Current in Gelatin Conductors of Different Forms (*a*), (*b*), (*c*), (*d*), (*e*), with Electrodes (1 and 2) in different positions. A, B, C, D, and E indicate the position of Thermometers, and the Figures at the ends of the Pointers show the rises of Temperature registered by the Thermometers at the ends of the experiments.

at A, B, C, D and E. The final rises of temperature at these spots are shown by the figures at the ends of the pointers. The electrodes are indicated by 1 and 2.

The conductor shown at (*a*) was rectangular in section. It will be observed that the maximum rise of temperature was obtained at C, midway between the electrodes, the minimal rise being at D, 1 cm. below the lateral surface. There was but little difference between the temperatures obtained at the different sites.

This experiment showed, first, the absence of a "skin-effect"; the rise of temperature was not restricted to the superficial parts of the gelatin; and second, the loss of heat by radiation and (air) convection; the temperature near the surface was lower than at the centre. At C the conditions were most favourable for the maintenance of the maximum temperature.

In the conductor indicated at (*b*) the maximum rise of temperature was recorded at D. There was no rise at B, and a slight one at C. The distribution of the current therefore was uneven. Seeing that the path for the current between the electrodes was shorter through D than through C or B, a greater concentration of current through D would have been expected. But judging by the temperature the concentration at D must have been higher than that which the shortness of the path through this spot would have demanded.

Attention has already been called to the disproportional concentration of the diathermic current along the shorter paths in the human body. It will be remembered that higher temperatures were recorded on the flexor aspects of the *bent* elbow and knee than on the same aspects of the *straightened* joints.

In the conductor indicated at (*c*) PQ and RS represent metal plate electrodes. The highest rise of temperature was obtained at E, and the lowest at A. This experiment illustrates the concentration of the current in the short path.

The conductor indicated at (*d*) was circular in cross section. The electrodes were curved and placed on opposite sides with their corresponding parts equidistant. The thermometers A and D were close to the surface, B was 6 cm. from A, C was 3 cm. from B and the same distance from D. The highest rises of temperature were obtained in the central portions of the conductor. Those at A and D were lower. Although the electrodes were closer together at A and D these spots were close to the surface and some heat was lost by radiation and by air currents.

The conductor and electrodes indicated at (*e*) had the same dimensions as at (*d*), but the electrodes were asymmetrically placed in relation to one another. Thermometers were placed at A, B′, B, C and D, each being 3 cm. from the adjoining one. The maximum rise of temperature was obtained, not at the centre (as was the case in the conductor (*d*)) but at that portion near the surface A where the edges of the electrodes were close together. The rise was maximum despite the fact that the situation of this spot was most favourable for loss of heat by radiation and convection by air currents. This experiment is an example of the edge-effect.

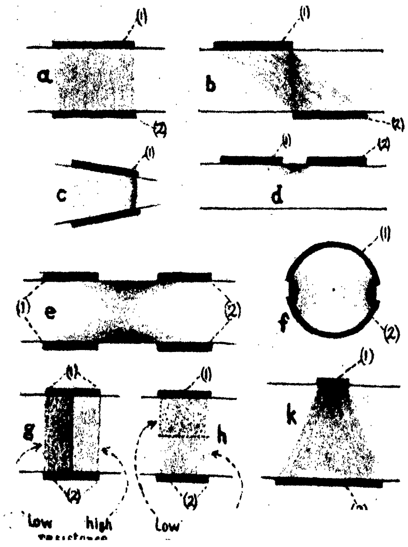


Fig. 70.—Pictorial Representation of different Degrees of Heat in Conductors of different Shape with Electrodes (1) and (2) in different relationship to each other and to the Conductors.

A pictorial representation of the relative degree of heating of homogeneous conductors of various shapes with electrodes in different positions is shown in Fig. 70. Uniform heating is indicated by even shading. Where the heating is not uniform the higher degrees are indicated by darker shading, and lower degrees by lighter shading.

(1) and (2) are the electrodes.

At **a** are represented flat electrodes on directly opposite aspects of the conductor and parallel to each other.

At **b** the electrodes are parallel but not directly opposite each other.

At **c** the electrodes are on opposite aspects and in oblique relationship to each other ; an edge-effect is represented.

At **d** the electrodes are on the *same* aspect of the conductor ; an edge-effect is indicated.

At **e** the conductor is cylindrical and each electrode encircles it completely. (The electrodes are seen in section.)

At **f** the electrodes are curved and placed on opposite aspects of a conductor which is circular in cross section. An edge-effect is produced in two situations.

At **g** the left half of the conductor has a lower resistance than the right half. They are grouped in *parallel* in relation to the electrodes. The portion with the *lower* resistance is heated to a *higher* degree.

At **h** the upper half of the conductor has a less high resistance than the lower half. They are grouped in *series* in relation to the electrodes. The portion with *lower* resistance is heated to a *lower* degree. (This difference is not indicated clearly enough in the figure.)

At **k** the electrodes are on opposite aspects of the conductor, (1) being much smaller than (2). A much higher degree of heat is produced under the smaller electrode.

## CHAPTER VIII

# HOW DIATHERMY IS APPLIED TO THE BODY

THERE are various ways of subjecting the body to diathermy. Some are employed for the purpose of heating the entire body and obtaining *general* diathermy, while others are utilised with the object of heating portions of it and obtaining *local* diathermy. For both purposes a pair of electrodes are required, also a couple of cables for connecting them to the diathermic machine.

### LOCAL DIATHERMY

When diathermy is to be administered locally both electrodes have, as a rule, to be placed on the *exterior* of the body, *i.e.*, on the skin, although in certain regions, such as the pelvic, one of the electrodes may be placed in one of the passages leading into the interior, the other being applied externally.

When both electrodes are placed on the exterior of the body they may be secured in position and kept stationary during the passage of the current. This is known as the "stabile" method of applying diathermy. On the other hand, one of the electrodes may slowly be moved over the skin of the region under treatment while the current is passing—without, of course, lifting it off the skin. This is known as the "labile" method of applying diathermy. The stabile method will be considered first.

### The Stabile Method of administering Local Diathermy

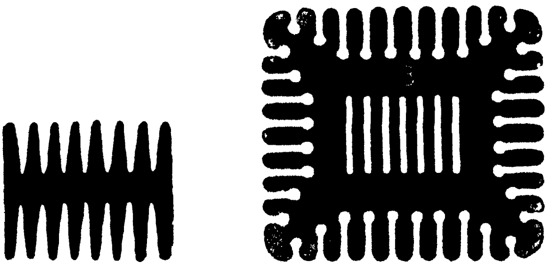
#### *Electrodes*

These are metal plates of various sizes and shapes. They are made of lead or a tin alloy and are sufficiently thin to be easily pliable. Each is provided with a clip or terminal for attachment of the cable which connects it to the machine. For application to flat or only slightly curved parts of the body the metal plates need not be cut or perforated. But if the part is markedly curved, like the shoulder, or irregular, such as the ankle, the metal will not make even contact unless it is fenestrated or cut in various ways, as illustrated in Fig. 71.[1]

Special electrodes are made for insertion into the rectum, uterus, etc. They are described in the chapters on the diathermic treatment of diseases of the pelvic organs.

### *Application of Electrodes to Skin*

To ensure accurate contact between the metal plate and the skin the latter should be moistened with water or lathered with soap. If the skin is hairy the soap lather is essential.



(*a*) (*b*)

FIG. 71.—Metal Plate Electrodes for application to the Skin. They are cut or fenestrated so as to enable uniform even application to curved or irregular surfaces.

If the skin is unduly dry and the metal plate placed in contact without moistening the epidermis, the patient will feel a sensation resembling that produced by a mild faradic current. The covered regions of the body are usually moist enough to prevent the faradic sensation, but it is advisable to damp the skin or apply the lather under the active electrode.

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[1] The electrode illustrated at (*b*) is one of the so-called "flow-line" electrodes. They were constructed in the belief that the current attains a greater density in the tissues under the edges than under the central portions of a plain non-perforated electrode. There is experimental evidence to show that this is the case when the distance between them is greater than their length or breadth. (See Experiment 7, p. 116.) But the density is not *much* greater under the peripheral portions, and the use of perforated or fenestrated electrodes is not likely to make it uniform.

The author prefers to interpose a moistened pad between the electrode and the skin. The pad is made of folded towel cloth and is well soaked in 10 per cent. salt solution. A half of an inch is a suitable thickness. The interposition of this pad has certain advantages. Uniform contact with irregular surfaces is easier to make. The preliminary moistening or soaping of the skin is unnecessary.

Some workers object to the insertion of a moistened pad between the metal and the skin. They say that the temperature of the pad will rise more than that of the skin and cause burning. This will certainly happen if the pad is soaked in *tap water* or in *salt solution of insufficient strength*, because the resistance of the pad will be higher than that of the skin. The current, therefore, will heat the former to a higher degree than the latter. The progressive rise of temperature of the pad can be studied by placing a thermometer with its bulb in the pad. If, however, the pad is soaked in *strong salt solution* its temperature will rise, but *pari passu* with that of the skin. Two tablespoonfuls of salt to a pint of water will make a solution of amply sufficient strength.[1]

### *Situation of the Electrodes*

Certain rules must be followed when deciding the situation of the electrodes. It has already been shown in the chapter on the heating of the body by the diathermic current that the electrodes must be placed in definite relation to each other and to the part requiring treatment if uniform heating (as far as this is possible) is to be obtained (pp. 133–135).

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[1] Kowarschik performed some experiments, which he describes in his book "Die Diathermie" (5th edition, p. 52), in order to ascertain the effect on the temperature when moistened pads were interposed between the metal electrode and the conductor. The conductor was composed of clay made up into a block with salt solution. Metal plate electrodes were placed on opposite aspects and a diathermic current was passed through. In the first set of experiments the electrodes were placed in direct contact with the clay. Only a slight difference of temperature was found between the surface and the centre. In the second set of experiments he interposed moistened pads of filter paper between the electrodes and the clay. A much higher temperature was recorded on the surface than in the centre. The reason for the greater heat on the surface was doubtless due to the use of "customary water" (*gewöhnliches Wasser*), *i.e.*, tap water, with which the pads were soaked. These pads had a higher resistance and were heated to a higher temperature than the clay. If they had been soaked in strong salt solution the difference would not have been noted.

When both electrodes are applied to the skin they should, as a general rule, be placed on *opposite* sides of the region to be treated. They should be placed in parallel planes, and the lines joining their corresponding parts should be as near as possible at right angles to the surface. If these rules are not followed there will be too great an inequality of the heating of the tissues between the electrodes, and the edge-effect may be produced.

If a region (*e.g.*, the shoulder) is to be heated in its entirety the electrodes should be equal in area. Both electrodes are then "active." If the part to be heated lies approximately midway between opposite surfaces the electrodes should be of the same area. If the part is not equidistant, but has a relatively superficial situation (*e.g.*, the heart, hip-joint, etc.) one electrode (active) should be placed on its surface-marking, and the other on the opposite aspect of the trunk or limb. The latter electrode is better termed the "directing" than the "inactive" electrode, because its correct situation ensures the distribution of the current in the part desired. It should have a larger area than the active electrode.

When a joint is to be treated it is undesirable that the electrodes should encircle the limb above and below the articulation. Attention has already been drawn to the concentration of heat in the soft tissues outside the joint when the current is directed *longitudinally* along the extremities. The current should be directed *transversely* across the joint by way of plate electrodes applied to opposite aspects. Where the joint is round rather than flat in cross section (as is the case with the knee) the width of the electrodes should be one quarter of the circumference. They should be placed first on the anterior and posterior aspects, and afterwards on the lateral aspects. In this way the edge-effect, which would occur if wider electrodes were used, can be avoided.

In those regions where the limb is flatter in cross section, such as the wrist and elbow, the electrodes need only be placed on the anterior and posterior aspects. Similar positions should be adopted in the case of the shoulder. In the case of the ankle they should be placed on the lateral aspects. To treat the sterno-clavicular and hip joints one electrode (active) should be applied to the superficial aspect. The directing electrodes should be placed respectively on the back of the thorax and the buttock. In the case of the finger and toe joints the electrodes should be placed on the flexor and extensor aspects. One or more of these joints can be included between the same pair of electrodes. To treat the spinal column and cord, one electrode should be placed over the vertebral column and the other on the anterior aspect of the trunk in the middle line. The most effective way of subjecting the hand to diathermy is to place the electrodes on the palmar and dorsal aspects. In the case of the foot, if one electrode is placed on the sole and the other on the dorsum, the edge-effect will occur at the outer part and anterior portion. In order to avoid it the electrodes must be placed in different positions. The following method is sometimes practised. The toes and the front of the foot are immersed in salt solution in a shallow trough. By raising the heel on a support the rest of the foot is kept out of the saline. One electrode is placed under the submerged portion of the foot. The other encircles the calf. A better way of subjecting the foot to diathermy is by means of the *labile* method (see below). To subject the brain to diathermy the electrodes may be placed on the temporal regions, or on the forehead and occiput. The hair must be well lathered with soap and water.

It has already been stated that the lines joining the corresponding parts of the electrode should be approximately at right angles to the surface. This rule need not invariably be followed. Suppose that the knee joint is to be subjected to diathermy. One electrode may be placed on the front of the thigh and the other on the calf. This is quite an efficient method. The current will attain a higher density between the lower edge of the thigh electrode and the upper edge of the calf electrode, and care must be taken not to overheat the skin in the situation of these edges. It is a slower method, but it seems to heat the knee more uniformly. Again, if it is desired to heat the patella and the pre-patellar bursa more than the rest of the joint the electrodes may be placed on the lateral aspects of the knee with their anterior edges less far apart than the posterior. Here, again, the patient and operator must collaborate in order to prevent overheating of the skin in the vicinity of the anterior edges.

Methods of applying diathermy to the urethra, uterus, uterine appendages, rectum, prostate, the eye and the ear will be described in the chapters dealing with the treatment of diseases of these parts.

### *Regulation of the Strength of the Current*

When diathermy is to be applied to parts under the skin and superficial fascia it is very important that the current should be *slowly* increased. The tissues do not at once reach the maximum temperature that the current can produce. The current, therefore, should not be *quickly* increased to the maximum required. It should reach this strength in stages and fifteen to thirty seconds should elapse between each increase. If the current is rapidly increased to its maximum in one stage the highly resistant fat in the superficial fascia will quickly become too hot and the current will have to be stopped before the better conducting tissues under the deep fascia have had time enough to become sufficiently hot.

It is also possible that a quick rise of temperature of the skin may influence the sensory nerve endings in the skin and cause reflex vaso-dilatation in the deep-lying organs. If this occurs and the vessels dilate, a larger quantity of blood will pass through the parts which they supply. More heat will then be lost by convection and the parts will not attain the temperature which could be reached if no vaso-dilatation occurred.

The maximum current which can be applied to a region is determined by the degree of heat that the tissues can tolerate without damage. If there is no diminution of sensation, the patient's feeling is a safe guide to the degree of heat that can be applied without risk. It is not always necessary to heat the skin to the maximum temperature which the patient can bear. The current which produces a comfortable warmth is generally sufficient.

The patient should always be told to give notice when he first feels the sensation of heat. Further increase of the current should then be delayed, because the sensation will increase a little, even if the current strength remains stationary. As soon, however, as the patient feels that the heat is no longer increasing the current may then be increased. This procedure is repeated until the patient feels a comfortable warmth. Further increase of the current makes the skin feel hotter and a stage may be reached when pain is felt in the skin, as well as heat. The moment when pain is felt the current must be reduced until it disappears.[1]

The patient should always be told to give notice if any part of the skin under the electrode becomes uncomfortably hot. The electrode should then be removed and the skin examined and felt by the operator. The first visible sign of unsafe heating is the appearance of a deep erythema (unlike the pink flush which is produced by the safe maximum heat). Œdema may then develop at the spot where the erythema is most intense and a blister form.

If there is any doubt of the patient's power to perceive the sensation of heat it is advisable to test the skin with hot water in a test tube. If heat sensation is lessened it is advisable to practise the *labile* method. If the skin is completely insensitive to heat the *stabile* method should always be avoided.

### The Labile Method of applying Local Diathermy

In this method one of the electrodes is stationary and the other is kept in movement by the operator. The stationary electrode is applied to one aspect of the part to be treated—as in the stabile method. The movable electrode has about one-third or one-quarter the area of the other. It is placed on the opposite aspect of the part. The current is started. With one hand the operator increases the current until the patient feels the sensation of warmth. Then, with the other hand, he slowly moves the "labile electrode" over those aspects of the part that are not covered by the stationary electrode. For most of the time he moves the labile electrode over those parts of the skin that are farthest away from the other electrode because the longer paths are slower in becoming hot than the shorter paths. Occasionally, however, he moves the electrode over the skin near the stationary electrode. During the séance the hand which holds the labile electrode can be kept in contact with the part under treatment, the purpose being to ascertain the degree to which it is being heated. The fingers of the other hand may also be used for the same purpose. The operator must take care, of course, that the skin under the *stationary* electrode does not overheat. If the sensation is not lost or impaired, the patient must be told to give notice if he feels the skin becoming painfully hot. If his power to perceive thermic sensation is lessened, or lost, the stationary electrode should be applied to another part of the body. Or, alternatively, the patient may rest on a condenser-couch (see below).

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[1] When neuritis accompanied by pain is being treated by diathermy the patient will sometimes feel an increase of the pain during the passage of the current, even though the skin under the electrode is not unduly hot. This, however, is not the pain of overheated skin, and it may be felt, in addition, in areas other than that covered by the electrode. The patient has no difficulty in distinguishing it from the burning pain due to the overheating of the skin.

The writer has used the labile method for many years and prefers it to the stabile method whenever *both* electrodes are applied to the skin. It has many advantages. As already stated, it gives the operator information as to the degree to which the patient's skin is being heated. This information is essential when the patient's sensation is impaired or lost. It also enables the operator to apply a more even degree of diathermy to regions where the electrodes cannot be placed parallel to one another. In the case of the foot, for example, if the stabile method is employed and one electrode placed on the sole and the other on the dorsum, they will be much closer together at the outer edge of the foot and in the regions of the toes. But if one electrode covers the sole and the other—a disc about 2 in. in diameter—is moved over the dorsum of the foot and allowed to remain for a longer time in movement over the thicker parts, an even degree of diathermy can be applied to the whole foot. By employing the labile method it is possible also to practise, in combination with the diathermy, a form of kneading massage which is useful in certain pathological conditions, *e.g.*, when adhesions are present.

The labile method has one limitation: the operator has to devote the whole of his time and attention to *one* patient while the diathermy is being administered. This may not be possible in busy hospital practice. But the advantages of the method easily outweigh this limitation. If the restriction of the service renders it necessary for the stabile method to be practised, the operator should always remain in the room where the patients are under treatment so that he can immediately attend to them should they complain of undue heating.

The labile method of course is impracticable when the active electrode is internally situated and when the part to be treated is quite small, such as the eye and ear.

### *Electrodes for Use in the Labile Method*

A disc of lead 1 mm. in thickness may be used as a labile electrode. A clip is secured to one side for attachment of the cable from the diathermic machine. A circular pad, made of a few layers of bath towel material, having a diameter considerably wider than that of the disc, is soaked in 10 per cent. salt solution. It is applied to the lead disc so as to envelop it completely on both sides. Its edges can be tied with tape around the cable attachment, or the operator can grasp them in place, the ulnar border of his hand making contact with the patient's skin when the

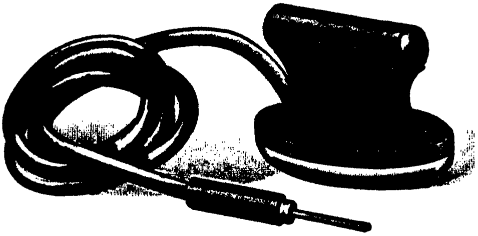

FIG. 72.—Electrode for Labile Administration of Diathermy.

electrode is in position.[1] The stationary electrode is similar to those employed when the stabile method is practised. To maintain it immovably in position the patient can lie on it if a region of the trunk is to be treated, or if a portion of an extremity requires treatment the patient can rest the limb on the stationary electrode.

### Administration of Local Diathermy on the Condenser Couch

This method is very convenient because the operator need apply only one electrode, thereby saving time. It is particularly useful for the administration of diathermy by the labile method. The condenser couch is described on p. 156 and illustrated in Fig. 74. The patient sits or reclines on the ebonite which forms the top of the couch. The metal plate under the ebonite constitutes an indifferent electrode. *It is connected to one of the terminals of the machine, the other terminal being connected to the active electrode which is applied to the region to be treated.*

The condenser couch is very convenient for the administration of diathermy in combination with certain forms of massage, viz., kneading and effleurage. Methods are described below.

It is probable, on the other hand, that the condenser couch method is less suitable than the others when the endeavour is made to heat the thoracic and abdominal organs. The large metal plate under the ebonite is merely an indifferent electrode for the purpose of completing the circuit. If an active and a directing electrode are both in contact with the skin there is theoretically more likelihood of obtaining deeper heating of the organs within the trunk than when the couch is used and no directing electrode employed.

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[1] Special electrodes are made by the Medical Supply Association for the administration of diathermy by the labile method. They are constructed on the same principle as that described, but they are more convenient to use. Quite recently the writer was shown a novel form of labile electrode which has recently been devised by Dr. Taylor-Pengelley. It consists of a block of white metal somewhat ovoid in shape, mounted on a black wooden handle. The cable for attachment to the diathermic machine passes out of the metal block, inside which it is securely attached. By reason of the shape of the metal the electrode would appear to be very suitable for making good contact with flat, curved or irregular surfaces. Dr. Taylor-Pengelley said that she had found the electrode efficient and convenient. Before it is used the skin is moistened with soap lather. The electrode is made by Stanley Cox, Ltd. (Fig. 72).

### Condenser Electrodes

These are made of glass and have various shapes (tubes, cones, etc.) and various sizes (Fig. 73). They are partly exhausted, so that the residual air becomes a fairly good conductor. A short platinum wire is sealed into one end. Any one of these electrodes can be attached to an insulating handle which is grasped by the operator. When attached the platinum wire is brought into connection with a terminal secured to the handle. The terminal is connected to one of the cables from the diathermic machine. The glass is placed in contact with the part of the body requiring treatment. The circuit is completed by means of an indifferent electrode. When the current is switched on and increased to a suitable strength the residual air in the glass electrode glows with a violet light and the skin in contact with the glass soon becomes hot and acquires a vivid erythema. Its glands are stimulated and the glass is soon covered with their dried secretion. In this method of applying the current through the skin the degree of diathermy of the deeper tissues is probably but slight. Strong currents cannot be used because the fine sparks, which have the appearance of a thin blue filament between the glass and skin, heat the epidermis strongly. These sparks, however, stimulate and increase the secretion of the sebaceous and sweat glands. They also form ozone and oxides of nitrogen from the air through which they pass. These gases are germicidal and exert this action in the superficial layers of the epidermis. After a short application of the electrode a strong odour of these gases can be noticed in the skin.

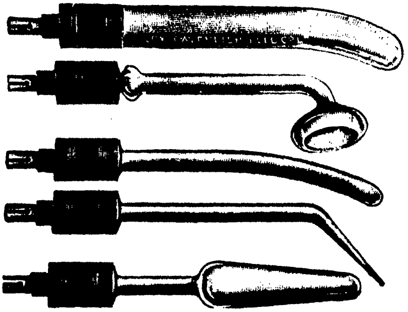

FIG. 73.—Condenser Electrodes.

The electrode is usually rubbed over the skin while the current is passing. A stronger current can then be applied without excessive heating of the skin, and a larger area treated in a shorter time.

Condenser electrodes of suitable shape and size are made for use in the rectum and vagina. When they are in position the contact of the glass with the mucous membrane is much more perfect than is the case when the glass is in apposition with the skin. As there is no film of air in between, there is no passage of sparks between the glass and the mucous membrane. Consequently there is no stimulation and no formation of germicidal gases. Only diathermy is obtained, and its degree only slight because the glass soon becomes quite hot even when a comparatively slight current is used. *One of the reasons for the heating of the glass is the high* temperature which the residuary air in the electrode attains when the current passes through it. There is no advantage, therefore, in the use of condenser electrodes in the vagina or rectum. On the contrary, there is a very real risk. These glass condenser electrodes are rather fragile and they may collapse when they are in position.

When the contact of the glass and a mucous membrane is imperfect, as is the case when a suitable electrode is introduced into the nasal cavity, there will be the passage of sparks—not where the glass is actually in contact with the mucous membrane—but just beyond, where the membrane is not quite in contact. Continuous slight shifting of the position of the electrode will enable the sparks to stimulate a considerable area of the mucous membrane.

Electrodes of the type above described are usually known as "vacuum electrodes" because they are partially exhausted. If they contained a complete vacuum they would not conduct the current.

Other types of condenser electrode are made. One consists of a glass tube filled with oil and contains a metal rod which occupies the position of its long axis. In this electrode the glass and oil act as the dielectric of the condenser and the metal rod as one of the armatures. By reason of the thickness of the dielectric the current supplied by the diathermic machine must be at a high voltage. These electrodes are strongly constructed and have been used for combining massage with superficial heating.

In another type the oil is replaced by powdered graphite. The latest type—and, in the opinion of the author, the best—is the so-called "non-vacuum." These are made of glass but contain air at atmospheric pressure. The inner surface of the glass is lined with silver which is brought into connection with a hook secured to the glass. The hook serves for attachment of the cable from the diathermic machine.

In this electrode the silver lining takes the place of the rarefied air as the internal armature. It has a much lower resistance. Although the violet glow[1] seen in the interior of the "vacuum" electrode is not observed when the non-vacuum type is used, there are the advantages that the electrode is less easily broken and the glass does not become so hot.

Diathermy applied by means of the condenser electrode is of value in some cases of acne vulgaris and septic infection of the skin and sebaceous glands. It is sometimes successful in chronic ulcers due to infection where other forms of treatment have failed.

## GENERAL DIATHERMY

The simplest way of subjecting the entire body to diathermy is to pass the current first along the upper limbs by way of cuff electrodes around the wrists, and afterwards along the lower limbs by way of similar electrodes around the ankles. By this method the limbs are heated *directly* by the current, and the trunk, neck and head *indirectly*, by convection, through the agency of the blood which is heated in its passage through the extremities. Strictly speaking, the trunk, neck and head are not subjected to diathermy in the same way as the extremities, because the current does not pass through them except in the pelvis and upper parts of the chest. They can, however, attain a higher temperature by convection than by passing the current through portions of them and heating them directly.

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[1] It may be mentioned here that the violet light plays no part whatever in the production of therapeutic results except in so far as it may impress the mind of the patient. If any *ultra-violet* rays are produced they will not pass through the glass. Small portable models of high-frequency current generators are made for use with "vacuum" electrodes and the administration of what is improperly called "violet ray treatment." This treatment, applied by means of the small generators, has the effect of heating and stimulating the skin. A small quantity of ozone and oxides of nitrogen is formed. This treatment is popular among barbers. The strength of the current is very small, and when it is applied by metal electrodes the *diathermy* is so minute as to be almost valueless except when minute portions of the body are treated.

A method used by some workers on the Continent is the following. Kowarschik applies a large plate electrode to the back and connects it with one of the cables from the diathermic machine. The other cable is connected to two pairs of cuff electrodes which encircle the lower parts of the forearms and legs. By this method the trunk is directly traversed by the current as well as the limbs, but it has the disadvantage that extra time and trouble are taken in applying the electrode to the back, and the patient is more exposed to the atmosphere, thereby losing more of the heat generated by the current.

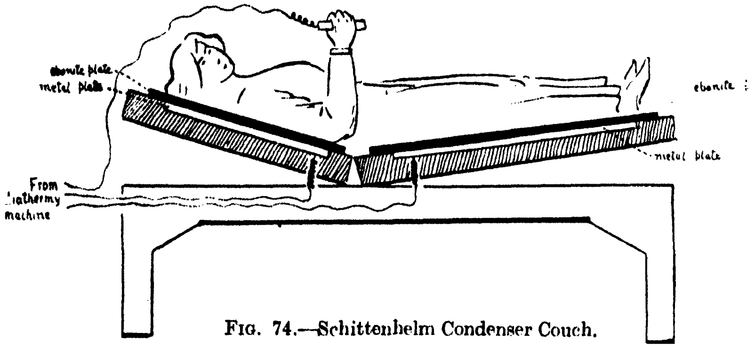

FIG. 74.—Schittenhelm Condenser Couch.

A third method, which, on the whole, is the most suitable and convenient, is one in which a condenser couch is used. Condenser couches for use with the high-frequency current generator of the d'Arsonval type have been employed for a long time. One suitable for the diathermic current was devised by Schittenhelm in June, 1911. It is shown in diagram in Fig. 74. In shape it resembles a long low table. It is made of wood. The top of the table is divided transversely into two parts and hinges secure the contiguous ends to the frame of the couch so that the ends can be raised, as shown in the figure.[1] The top of each division is covered with sheet ebonite. Under the ebonite are secured four metal sheets, two lying side by side under the upper division and two lying similarly under the lower division At the head end of the couch is a box containing five crank switches. By means of these either of the metal sheets can be electrically connected to either pole of the diathermic machine. By means of the fifth switch either pole of the machine can be connected to the electrode which is applied to the patient.

When the condenser couch is used for the application of general diathermy, one of two methods may be adopted.

In the first, and more usual, all four metal sheets are brought into connection with one pole of the diathermic machine.

The patient reclines on the couch. A cuff electrode is placed around each wrist. These two electrodes are connected by a cable, and a second cable connects them to the other pole of the diathermic machine. Later, during the same séance, the cuff electrodes are removed from the wrists and a similar pair applied to the ankles. These electrodes are similarly connected to the diathermic machine. By this method the limbs are heated directly by the current and they attain a higher temperature than the trunk. The trunk is heated mainly by convection, as in the method first described, but the parts which are closest to the ebonite are heated directly, though only to a slight degree, and it is unlikely that the organs within the body cavity are heated directly. The heating of the parts that are separated from the ebonite only by the patient's garments is self-evident if he is in a sitting, rather than a reclining, position

In the second method of administering general diathermy on the condenser couch there are no electrodes in contact with the body. By means of the crank switches the two metal sheets under the right side of the body are connected to one pole of the machine, and those under the left side are connected to the other pole. Alternatively, one pole can be connected to the two sheets under the upper portion of the body, and the second pole to the sheets under the lower portion. Only minor degrees of general diathermy can be obtained by this procedure.

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[1] It is more comfortable for the patient if the division which supports the lower limbs is also divided and hinged. It can then be bent and the patient can flex his knees and avoid the discomfort of full extension.

When general diathermy is given, by any of the methods that have been described, the hands and feet are the last parts to feel warm and show a rise of temperature. They are heated by convection, but as their temperature is usually subnormal, a longer time is occupied in attaining the same degree of heat as the other parts of the body. If the hands and feet are abnormally chilly they may feel but little warmer at the end than at the beginning of a twenty minutes' séance. They gradually become warmer after the treatment is ended, but if coldness of the feet and hands is a distressing symptom it is advisable to apply local diathermy to these parts at the conclusion of the general treatment.

### PRODUCTION OF HIGHER DEGREES OF GENERAL DIATHERMY (ELECTROPYREXIA)

When a patient is attired in his ordinary indoor clothes it is not easy, by any of the methods above described, to raise his general temperature more than about two or three degrees Fahrenheit—or a trifle more, if it is subnormal at the commencement. Prolongation of the séance does not cause a further rise of temperature because the rate at which heat is lost begins to increase. A higher temperature can be procured in one of two ways.

The first is to produce diathermy at a faster rate. This can be done by using two machines simultaneously, passing the current from one along the upper limbs, and the current from the other along the lower limbs. The author tried this method on a patient whose temperature on a previous occasion could not be raised above 101° F. when a single machine had been employed. With two machines the temperature rose to 104·6° F. The patient had been conveyed to the electrical department from the ward. Attired in pyjamas and a dressing gown he was placed on a couch and covered with rugs. Sweat dripped from the patient during the treatment and a pool of it was discovered on the floor.

The second way of obtaining a higher general temperature is to employ a single machine and at the same time adopt some method which will prevent loss of heat.

One method is to administer the diathermy to the patient when he is in a full-length bath and immersed in hot water. The disadvantage of this method is the hydrostatic pressure of the water, which is an additional discomfort to the patient when he is beginning to feel exhausted in consequence of the higher rise of his temperature. Although the use of a foam bath would relieve him of the pressure of the water there remains the labour of preparation and the inconvenience of treatment of this kind in an electrotherapeutic department. It must be realised that elevation of a patient's temperature to 103° or 104° F. cannot satisfactorily or safely be practised on ambulatory cases. The treatment

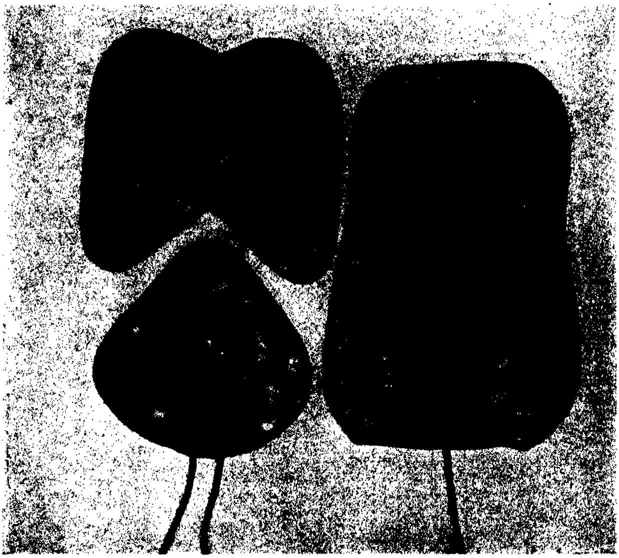

FIG. 75.—Electrodes used by Neymann and Osborne for producing therapeutic fever by diathermic current. That on *right* is applied to back of trunk; those on *left* to front (upper one to chest, lower one to abdomen).

should be conducted in the wards of hospitals or institutes. It should be administered to the patient while he is in bed. Loss of heat can almost entirely be prevented by wrapping the body with blankets and mackintosh cloth.

In regard to the electrodes and their situation it has been found that the most suitable position is the trunk. Special electrodes were designed by Neymann and Osborne. They are illustrated in Fig. 75. They are made of pliable metal and are fenestrated. They are mounted on spongy rubber which has a slightly larger area and is ½ in. thick. The electrode shown on the right is applied to the back. The two electrodes shown on the left are applied to the anterior aspect of the trunk, the upper to the chest and the lower to the abdomen. The skin is covered with soap lather in order to ensure perfect contact between it and the metal. The electrode on the back is connected to one of the terminals of the diathermic machine. The electrode on the chest is connected to the other terminal. That on the abdomen is connected to the same terminal as the chest electrode but with a rheostat interposed. The reason for the use of *two* electrodes on the anterior aspect of the trunk is the fact that the impedance offered to the current by the abdomen is about half the amount offered by the chest. If a single electrode covered the front of the trunk the current would overheat the abdomen or underheat the chest. But by using two electrodes and introducing an additional impedance into the circuit between the machine and the abdominal electrode the density of current in the abdomen can be made as nearly as possible the same as that in the chest.

The electrodes are maintained in position by means of rubber straps. If it is suspected that the patient may become unruly during the treatment it will be safer to keep the electrodes in position by means of a restraining jacket. This precaution is advisable before beginning the treatment in some cases of dementia paralytica—the disease for which the method now being described was originally elaborated.

A rubber sheet is placed on the bed which is to receive the patient. Over it are placed a couple of blankets. The patient, lying on them, is covered with two more blankets, and on them is placed a second rubber sheet. Lastly, two more blankets are placed over this rubber sheet and tucked in on both sides and at the foot of the bed.

The diathermic machine should be one of full size and capable of yielding a current of 3 to 6 amperes when the body is placed in the circuit in the way described. It should be able to give the current continuously for two to three hours without overheating.

It is absolutely essential to measure the temperature of the patient at intervals during the treatment. Safety in treatment and accuracy in dosage are impossible unless the general temperature is known. It should be ascertained every quarter of an hour while it is rising to its maximum, and every five minutes after it has attained its maximum. Neymann says that the rectal, rather than the oral, temperature should be obtained. He employs a rectal resistance thermometer. Its readings are continuously recorded on a moving sheet of paper. The use of a pyrometer of this kind not only saves the trouble caused by periodic insertion and removal of a rectal thermometer, but in addition it enables the operator to observe from moment to moment the effect which the treatment is having on the heat-regulating mechanism.

As in all forms of medical diathermic treatment the increase of the current should be gradual. The operator should expend from twenty to thirty minutes in increasing the current from zero to maximum. The maximum value which it should attain must be judged from the height and weight of the patient. Small patients do not need more than about 3 amperes, whereas tall, stout, massive subjects are likely to require 5 to 6 amperes.

The patient's temperature does not rise *pari passu* with the increase of the current. It rises much more slowly, and when the current has attained its maximum strength the temperature of the body will be found to have risen only two or three degrees. The current is allowed to remain at the same strength. The patient's temperature, however, continues to rise, slowly at first, but afterwards more rapidly. From one-and-a-half to two hours should be occupied in elevating the temperature to a maximum of 104·6° or 105°. If it should rise too rapidly the current should be reduced and, if necessary, some of the patient's coverings removed. When the temperature reaches the values stated the current is stopped. In spite of the stoppage the temperature continues to rise, though not more than one degree. Then it begins to fall. The rate at which it falls is determined by the rate at which the patient loses heat. If his coverings are allowed to remain in position it may not reach its normal value before five, six or even seven hours have elapsed. In some cases, however, it will fall much less slowly and it may be necessary to start the current again.

With experience, the operator is able to control the rate at which the temperature reaches the desired maximum. He has to judge from the size of the patient the strength which the current must reach. He is also able to maintain the temperature approximately at the level desired; it may be necessary to pass the current again from time to time. He can also reduce the temperature to its normal value more rapidly than would occur spontaneously, by removing the patient's coverings. Should a dangerous degree of heat be reached it can be reduced to a safe value by sponging the body with cold water.

As would be expected, the patient suffers considerable malaise. It commences when the temperature reaches 103° or 104° and he may become semi-delirious. If this happens it is advisable to administer morphine. A specially trained nurse should be continuously in attendance.

When the method above described is utilised for the production of electropyrexia the part of the procedure which requires the greatest care is the application of the electrodes. Unless they are secured immovably in position there will be a risk of damage to the skin, more particularly if the patient becomes unruly. Prevention of burns cannot entirely be guaranteed, although the risk is slight with careful technique. Of late, Neymann has been employing the inductothermic method of producing electropyrexia. He finds it safer. The technique also is simpler. A short account of inductothermy and the inductothermic method of treatment is given in Section IV. There is also a third electrothermic method of producing electropyrexia. It is the so-called " short-wave " method. It has the advantage that no electrodes are in contact with the body. But there is less control over the thermogenetic action of the current than with the other methods. Further information on this method is given in Section III.

### THE DIATHERMIC CURRENT IN COMBINATION WITH OTHER CURRENTS

While the body is being subjected to diathermy it is possible to pass the galvanic, faradic or sinusoidal current at the same time by way of the same electrodes. Hence the therapeutic action of one or another of these currents can be added to that of diathermy.[1]

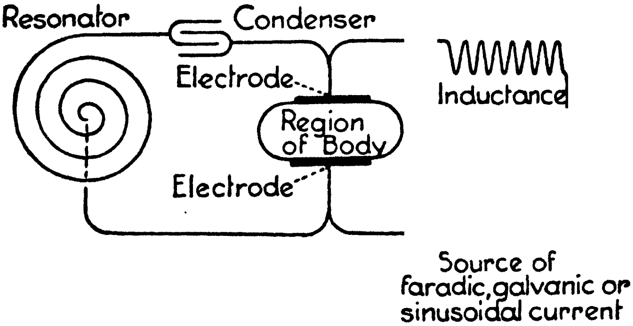

FIG. 76.—Plan showing connections of apparatus when diathermic current is used in combination with other currents.

Since the same two electrodes are used, both for the diathermic and the additional current, it is necessary to adopt some device in order to prevent the diathermic current passing through the apparatus from which the additional current is derived. At the same time the additional current must be prevented from passing through the diathermic machine. It will be remembered that one or two condensers are placed in the circuit between the resonator and the patient (see Fig. 40, p. 73). These condensers prevent the passage of the additional current through the resonator; it can pass only through the patient. The diathermic current can almost entirely be prevented from passing through the source of the additional current by including a coil of wire in the circuit between this source and the electrodes. It will be remembered that an extremely high resistance (impedance) is offered to high-frequency oscillatory currents by a coil of wire containing a number of closely adjacent turns. If the wire is thick the resistance which it will offer to the additional current will be very small.

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[1] It appears that Dr. Annibal Varges, of Rio de Janeiro, Brazil, was the first, in 1925, to devise a method of using the galvanic and diathermic currents in combination and employ the combined "galvanodiathermic" current for therapeutic purposes.

The position of the condenser and coil in the circuits is shown in Fig. 76. Some diathermic machines, such as the Standard "Intertherm" (p. 88) and the "Dreadnought" (p. 91), contain the necessary coil. A small cabinet containing a condenser and coil can be used with a diathermic machine that is not fitted with a condenser in the resonating circuit or a resistance coil. It is constructed by Stanley Cox Ltd.

The diathermic current, in combination with others, does not possess any properties other than those of the component currents. The combined current is useful, however, in cases where the region to be treated by the galvanic, faradic or sinusoidal current has a subnormal temperature. Heat increases the biological action of these currents.

## COMBINATION OF DIATHERMY WITH MASSAGE

It is possible to apply stroking and kneading movements to the body and administer diathermy at the same time. There are various ways of giving the combined treatment.

The simplest is the following. A plate electrode is placed on one aspect of the part to be treated. The patient should rest the limb or trunk on this electrode so as to keep it in place and leave the other aspect free for the hand of the masseuse. This electrode is connected to one of the terminals of the diathermic machine. The other terminal is connected to a belt electrode which is secured in position around the right wrist of the masseuse. She places her right hand on that aspect of the part to be treated which is uncovered by the electrode. With her other hand she switches on the current and regulates its strength, while the right hand performs the massage. The disadvantage of this method is the fact that the electrode must afterwards be placed in another situation when the part which was in contact with it is to be massaged.

In the second method a condenser couch is employed. The patient sits or reclines on it. He is connected to one of the terminals of the machine, either by a rod electrode grasped in the hands, or by belt electrodes placed around the legs above the ankles. The masseuse places her right hand on the part to be treated and regulates the current. After the current has reached a sufficient intensity she may use the left hand as well as the right for administering the massage. In this method the greater portion of the body is in the circuit. Some of the current passes between the body and the hand in contact because the masseuse is approximately at zero potential. The patient receives *general,* as well as local, diathermy while the massage is administered.

In the third method the patient rests on the ebonite over the pair of metal plates at the lower end of the couch. These plates are connected to one of the terminals of the machine. The masseuse sits on the ebonite overlying the metal plates at the upper end of the couch. These plates are connected to the other terminal of the machine. With the palm of one hand on the patient the masseuse regulates the current with the other hand. When the current has attained the desired strength she can use both hands for administering the massage.

When any of these methods are practised the massaging hand must not leave contact with the patient's body while the current is passing. The current must be switched off before the hand is taken away.

The condenser couch methods of giving the combined treatment are the best because the operator has both hands free for the purpose of massage. In addition, there is no need to fix a metal electrode on the part to be treated. The massaging hand plays the part of a labile electrode.

## CHAPTER IX

# THE ACTION OF DIATHERMY ON THE BODY IN HEALTH

### WHY THE DIATHERMIC CURRENT IS UNABLE TO STIMULATE THE EXCITABLE TISSUES

THE most striking feature of currents which oscillate with high frequency is their inability to stimulate muscle or nerve to give their customary physiological response, even when their intensity attains that of the diathermic current. For many years there was no satisfactory explanation. Modern research on the electrical excitability of muscle and nerve has shed light on the subject. The power of an electric current to stimulate depends not only on its strength, but also on the time for which it lasts. If its duration is exceedingly short its power to stimulate is reduced or even lost. The stronger the current the shorter must be its duration if it is to lose its power to stimulate. If a current oscillates with a frequency of 500,000 cycles per second its duration before each reversal is one-millionth of a second. This is so brief that no stimulation is effected, even if the strength of the current is 1, 2 or 3 amperes.

### SOME OBSERVATIONS ON THE INFLUENCE OF DIATHERMY ON THE CIRCULATION

### Local Hyperæmia

One of the most important physiological properties of the diathermy current is its power to cause active hyperæmia of the tissues through which it passes. The hyperæmia is caused, in part, by the dilatation of the blood vessels. Evidence of vaso-dilatation is shown by the erythema of the skin under the electrodes. The degree of erythema, however, is surprisingly slight considering the temperature to which the skin may be raised. Thus, a patient whose forearm was being traversed transversely by the *galvanic* current, by way of an electrode placed on the surface, acquired a vivid erythema of the skin, the temperature of which rose to 98·6°. The opposite forearm was subjected to diathermy. The skin under the electrode reached a temperature of 100°, but scarcely any erythema was visible. Even when the skin temperature was raised to 103° or 104°, the erythema was slight. The erythema induced by the galvanic current was due to vaso-dilatation reflexly produced by stimulation of the sensory nerve endings in the skin. The high-frequency current was unable to stimulate these nerve endings in the same way, and the slight erythema was due probably to direct warming of the subcutaneous vessels.

Hyperæmia following diathermy is due also to a diminution of the resistance encountered by the blood in its passage through the arterioles and capillaries. Heat lessens the viscosity of the blood, thereby enabling it to pass through the vessels with less frictional resistance. The circulation is therefore accelerated and the heated region receives more blood per unit of time. By reason of the slight degree of vaso-dilatation it seems likely that the diminution of the viscosity of the blood is the more potent factor in causing the hyperæmia. The heated parts not only hold more blood, but the supply is more rapidly renewed.

## Influence of Diathermy on the Arterial Blood Pressure

The arterial blood pressure is influenced by various physical factors, viz., the force and rate of the heart beat, the peripheral resistance to the blood flow (especially that encountered in the arterioles, capillaries and small veins), the elasticity of the vessel walls, and the amount of blood in the system. Diathermy cannot alter the amount of blood in the system and it is unlikely that it can modify the elasticity of the arteries. But it can diminish the peripheral resistance. Cardiac muscle is also influenced by heat; experiments on animals show that, within physiological limits, the rate and force of contraction are increased by a rise of temperature. For these reasons diathermy should influence the arterial pressure in normal subjects.

In order to obtain information on the subject the writer applied diathermy to normal subjects and to patients who were without cardio-vascular disease or constitutional maladies. Two sets of experiments were conducted.

In the first set the current was directed along the upper limbs, the object being to heat the whole of the blood in the body.

In the second set the electrodes were placed on the chest—one on the præcordium and the other on the back of the chest. The object was to heat as much of the cardiac muscle as possible.

(1) *Results of Heating the Whole Blood.* After diathermy had been applied to the upper limbs the following results were found. When the pressure was low at the commencement the diathermy produced little or no fall. When the pressure was high at the commencement diathermy was, in some cases, not in all, followed by a more pronounced fall. These were the results noted when the diathermy was applied for periods of twenty to thirty minutes, and the current not strong enough to produce unpleasant and oppressive heat. Before applying the diathermy, the patient was kept at rest, so as to allow the blood pressure to sink to a stationary value. The following experiments illustrate the above-mentioned effects. In the first, the pressure, which was low at the commencement of the diathermy, was only slightly reduced, even after a long application.

EXPERIMENT 1. The patient (M. B., *æt.* 21), who suffered from arthritis, was subjected to general diathermy, the current being passed along the upper limbs. The following changes in the systolic blood pressure were noted :—

| | |
|---|---|
| Before diathermy . . . . | 94 mm. |
| After 10 minutes . . . . | 90 mm. |
| After 25 minutes . . . . | 90 mm. |
| After 30 minutes . . . . | 95 mm. |
| After 35 minutes . . . . | 88 mm. |

At the end of the diathermy the oral temperature had risen 0·4°, the axillary temperature 1·2°, and the groin temperature 0·4°. The patient felt comfortably warm after the treatment. The fall of pressure was slight, only 6 mm.

EXPERIMENT 2. On another occasion diathermy was applied to the same patient in the same way, but a stronger current was used. Before diathermy the pressure was 98 mm. After thirty minutes the patient complained of faintness and felt dizzy. The pressure was measured and found to be 65 mm. The patient felt uncomfortably hot and the oral temperature had risen 1·4° (from 98·6 to 100). A fall as low as this is rare, in the author's experience.

In the next case the pressure was relatively high before the diathermy. It fell 18 mm. during the diathermy.

EXPERIMENT 3. The patient (M. P., *æt.* 17), who had suffered from a habit chorea, and presented no signs of cardio-vascular disease, was subjected to diathermy in the same way as the case mentioned above. The following changes in the systolic pressure were noted :—

| | |
|---|---|
| Before diathermy . . . . | 128 mm. |
| After 10 minutes . . . . | 118 mm. |
| After 30 minutes . . . . | 112 mm. |

When diathermy is applied to the *normal* subject in sufficient amount to raise the internal temperature, the results which the author usually found were a lowering of the systolic pressure and an increase in the pulse rate.

In the following observation the subject (female, *æt.* 30) was placed on the diathermy condenser couch [1] and allowed to rest there, holding the electrode in both hands, so that the current was directed along the upper limbs. The apparatus was first set in operation, but no current was passed at first, in order to allow the pulse rate and pressure to reach a stationary value, and allow any psychic influence to subside.

| EXPERIMENT 4. | Temperature. | Pulse. | Systolic pressure. |
|---|---|---|---|
| At beginning of observation . | 98·6 | 104 | 140 |
| After 5 minutes' rest . . | 98·6 | 92 | 120 |
| After 10 minutes' rest . . | 98·6 | 92 | 120 |
| After 5 minutes' diathermy . | 98·8 | 102 | 116 |
| After 10 minutes' diathermy . | 99·4 | 106 | 112 |

The figures above show that after ten minutes the pulse rate increased by 14 beats per minute, and that the pressure fell 8 mm. The temperature rose 0·8°.

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[1] This method of applying diathermy is described on p. 152.

In the next observation (female, *æt* 25), diathermy was applied in the same way as described above, but the current was allowed to flow for twenty minutes after the pulse rate and pressure had reached a stationary value.

| EXPERIMENT 5. | Temperature. | Pulse. | Systolic pressure. |
|---|---|---|---|
| Before diathermy . . . | 98·6 | 84 | 122 |
| After diathermy for 7 minutes | 99·2 | 92 | 115 |
| After diathermy for 14 minutes | 99·6 | 94 | 106 |
| After diathermy for 20 minutes | 99·8 | 94 | 104 |

In experiments of the kind described above, it will be realised that the blood, heated in its passage through the arms, conveys heat to other parts, not only to the walls of the vessels, but also to the cardiac muscle. Theoretically, this indirect heating of the heart would tend to increase the force and rate of the heart beat and therefore *raise* the blood pressure. In the above-described experiments the net result, when the diathermy was given in amounts sufficient to raise the general temperature one or two degrees, was to lower the systolic pressure and increase the pulse rate.

(2) *Results of Heating the Heart Muscle.* In the next set of experiments the current was directed through the heart. By reason of its situation and the presence of additional paths for the current around the organ it is doubtful whether the heart, except the anterior wall, can be heated more than a trifling degree. When the heart is on the path of the diathermic current the possibility of the heating of the blood within it must be kept in mind. But as the duration of stay of the blood within the heart is brief it is unlikely to be heated more than a small fraction of a degree. Hence, when diathermy is applied to the heart, its effect on the blood pressure should, theoretically, be the result of heat mainly on the heart muscle.

In Experiment 6 an electrode equal in area to that of the præcordium was placed over the heart. The current was increased until the skin under the electrode was as hot as could be borne without pain. The following figures were obtained :—

| EXPERIMENT 6. | Temperature. | Pulse. | Systolic pressure. |
|---|---|---|---|
| Before diathermy | 97·8 | 74 | 108 |
| After 5 minutes' diathermy | 97·8 | 78 | 108 |
| After 10 minutes' diathermy | 97·9 | 76 | 102 |
| After 15 minutes' diathermy | 98·0 | 72 | 106 |
| After 20 minutes' diathermy | 98·2 | 80 | 108 |

In this experiment the internal temperature rose only 0·4° F., and the systolic pressure and pulse rate were inappreciably altered.

In the next experiment a larger electrode was applied to the præcordium with the object of passing a stronger current and obtaining a higher internal temperature.

| EXPERIMENT 7. | Temperature. | Pulse. | Systolic pressure. |
|---|---|---|---|
| Before diathermy | 97·2 | 80 | 130 |
| After 5 minutes' diathermy | 97·3 | 80 | 126 |
| After 10 minutes' diathermy | 97·9 | 80 | 120 |
| After 15 minutes' diathermy | 98·3 | 84 | 116 |
| After 20 minutes' diathermy | 98·4 | 86 | 116 |

The pulse rate increased by 6, and the systolic pressure fell 14 mm. The internal temperature rose 1·2°.

The *fall* of the systolic pressure was due, perhaps, to the fact that a portion of each lung was included in the circuit by using a large electrode. The lungs are highly vascular, and if they are subjected to diathermy the blood is heated and the peripheral resistance to its flow diminished.

It seems, then, that when diathermy is applied to the normal subject, either to the peripheral or central regions of the circulation, and in amount sufficient to raise the internal temperature one or two degrees, the results are a fall of the systolic pressure and an increase of the pulse rate. Occasionally, however, a slight fall of pressure was obtained without increase of the pulse rate. In one experiment a small *rise* of pressure was observed (the pulse rate remaining unchanged) when a slight degree of diathermy was applied to the heart.

Accurate observations on the influence of diathermy on the blood pressure are not easy to make. The psychic effect of the machine and of the measurement can easily explain a rise of pressure and increase of pulse rate, and obscure any effect which the diathermy may cause. The fall of pressure and increase of pulse rate are frequently slight, but as these changes have been noted in a fair proportion of normal subjects, when precautions were taken to remove extraneous influence, the changes above noted may reasonably be regarded as the effect of diathermy on the normal cardiovascular system.

### Influence of Diathermy on the Respiratory Exchange and Metabolism

Some interesting observations were made on the respiratory exchange during and after diathermy by Réchou (quoted by Bergonié, *Archiv. d'Élect. Méd.*, March 10, 1913). After diathermy for thirty minutes the subject was consuming less oxygen and giving off less carbon dioxide. At the beginning of the diathermy the oxygen intake and the carbon dioxide output both increased. Before the diathermy the oxygen consumed (during ten minutes) was 2·95 litres. At the beginning of the diathermy, the oxygen consumption was 3·63 litres, but after the diathermy had lasted for thirty minutes it fell to 2·14 litres. The figures for the carbon dioxide output were—before diathermy, 2·62 litres; at the beginning of diathermy 3·16 litres; after thirty minutes' diathermy, 1·96 litres. The volume of oxygen inhaled is a measure of the metabolism of the body. The observations of Réchou show, therefore, that the first effect of diathermy is an increase of metabolism. The final effect, however, is a diminution of metabolism below that which occurs before the commencement of diathermy.

It is interesting to recall the earlier work by d'Arsonval on the influence of high-frequency currents on metabolism. It was shown by this distinguished pioneer that the metabolic changes were increased. The increase was due, doubtless, to the stimulating action of the small amount of heat produced in the body by the earlier high-frequency current-generator. The physiological fire was fanned and made to burn more fiercely. On the other hand, the large quantity of heat produced by the modern diathermic machine lessens metabolism, although the first action of the heat, before sufficient time has elapsed for its production in large amount, is to increase the metabolism.

The production of heat by the body in order to replace that which is being continuously lost is the result of katabolic changes. If the heat is supplied artificially by the diathermic current the katabolism is lessened, although the first effect of the heat is to increase it, as shown by the experiments of d'Arsonval and Réchou.

Réchou found acetone in the urine of adipose subjects after applications of diathermy.

### Experiments on Animals

Some experiments were made by Nagelschmidt to ascertain the effect of diathermy on different organs of animals. The results were published in his "Lehrbuch der Diathermie." In some of these, the exposed heart of a dog was subjected to diathermy by means of electrodes placed directly on the organ. The effect of raising the temperature of the muscle was at once to accelerate the rate of beat. In some cases the rate was doubled. At the same time the blood pressure rose. After the cessation of the diathermy the pressure began to fall and the pulse rate to decrease, and in a few minutes both reached their original values.

In another experiment one electrode was placed on the spine, the other on the sternum, of a narcotised dog. The effect of the diathermy current (500 milliamperes) directed antero-posteriorly was to cause, after twenty seconds, a slight rise of blood pressure. It stayed at a constant level during the diathermy and slowly fell after the diathermy was discontinued. When the electrodes were placed on the lateral aspect of the thorax, one on each side, the amplitude of the respiration was slightly increased while using the same strength of current. When the current was increased to 1,700 milliamperes the respirations were deeper and slightly less frequent. The pulse rate was slightly accelerated. After the diathermy the respiration regained its former character. The temperature in the mediastinum rose 3·6° F. Further increase of the current deepened and markedly slowed the respiration, and, finally, breathing stopped. The mediastinum temperature then was raised by 7·2° F.

The temperature of the brain can be raised in the living animal by diathermy when electrodes are placed on the exterior of the skull. Clœtta and Waser (*Archiv. für Experimentale Pathologie und Pharmakologie*, June 25, 1914) showed a rise of 1° C. in the lateral ventricle of a dog after diathermy for ten minutes. The temperature fell to normal in ten minutes after stopping the diathermy.

Nagelschmidt applied diathermy to the medulla oblongata of a dog, and the respirations assumed a deep gasping character, probably from heating of the respiratory centre.

Furstenberg and Schemel were able to demonstrate a rise of temperature in the stomach by directing a diathermic current through the abdomen of a dog. They showed, in addition, that stronger currents produced a *slighter* rise than weaker currents. This apparent paradox is explained by assuming that intense heating of the skin by strong currents caused a reflex vaso-dilatation of the gastric blood vessels and a removal of heat from the stomach by convection. When the animal was killed and the circulation stopped it was found that stronger currents produced a higher rise of temperature in the stomach, and *vice versâ*.

# CHAPTER X

# THERAPEUTIC ACTION AND PROPERTIES OF DIATHERMY

## Mode of Action of the Diathermic Current

THE therapeutic effects which follow the passage of the diathermic current through the body are those of heat. When diathermy cures disease or relieves symptoms after other forms of thermotherapy have failed the reason for its success must be attributed to the fact that the diathermic current is able to heat the body to a depth greater than that which can be reached by heat derived from hot objects outside the body.

It serves no useful purpose to assume that high-frequency currents capable of producing diathermy can cure or relieve disease in any other way than by the production of heat. In maladies in which the therapeutic value of diathermy is established the effects of the treatment can be satisfactorily attributed to the production of heat. The hypothesis that they are due, partly or wholly, to some other action of the current, as, for example, " massage of the protoplasm " by the oscillating ions, affords no guide to the selection of maladies suitable for treatment. It must be remembered that the inability to find explanations—other than those which themselves required explaining—of the method of action of high-frequency currents on the body, in the days when they were first used for treatment, caused high-frequency treatment gradually to fall into a " slough of despond " from which it was rescued only when it was taught that the therapeutic effects of these currents were due to the production of heat.

The controversy waged during the first ten years of the present century as to the mode of action of high-frequency currents in therapy sank into obscurity during the second and third decades after the establishment of diathermic treatment. But it again came to the fore after the introduction into medicine of currents of much higher frequencies. After a long lull the storm has broken out afresh. It is still " quiet on the diathermy front " but a conflict is being waged as to the *modus operandi* of currents of ultra-high frequency. This subject will be discussed in the Section dealing with short-wave treatment. But in regard to currents of less high frequency, like those employed in diathermic treatment, the following experiment, originally conducted by d'Arsonval and Charrin, should be borne in mind. They showed that the toxicity of diphtheritic toxin was diminished after it had been subjected to the action of a high-frequency current. They maintained that the effect could not have been due to heat because the chamber containing the toxin was exposed to the cooling action of a stream of water. It is possible, however, to heat particles in a colloidal solution without raising the temperature of the solution as a whole. The colloidal molecules of the toxin, with the fluid around them, could act as a number of microscopic condensers and they might be heated selectively by displacement currents, without a rise of temperature in the fluid as a whole.

### Advantages of Employing Diathermy for Thermotherapeutic Purposes

The following advantages are gained by using the diathermic current for procuring the therapeutic effects of heat.

In the first place, the current is able to heat to a greater depth below the surface than can be reached when hot objects are placed in contact with the skin or when the skin is exposed to the action of radiant heat.

Secondly, by placing an electrode in one or another of the passages leading into the pelvis, the organs within the pelvic cavity can be heated—some of them several degrees. The inability of the current to heat the interior of the pelvis—when *both* electrodes are on the exterior—has already been proved. Although hot water or hot metal rods can be placed in the channels they do not procure heating of the parts below the mucous membranes.

Thirdly, the diathermic current provides a *continuous supply* of heat for any length of time. Although electrically heated pads do the same they are unable to heat to the depth attained by means of the diathermic current.

### Therapeutic Properties of Diathermy

In the treatment of symptoms, such as pain and spasm, the value of heat is well known and diathermy is sometimes able to provide relief after epithermy has failed. By reason of its power to procure deep heating it may be able to exert its therapeutic action on the pathological conditions responsible for the symptoms. For example, both the local and the referred pain due to fibrositis are more likely to receive permanent relief from diathermy than from epithermy, because the last-mentioned will heat the skin only, whereas diathermy, in addition, will heat the inflamed fibrous tissue. Again, epithermy cannot effectively reach an anal fissure nor can it heat the sphincter, but both parts can easily be heated by the diathermic current. The heat aids the healing of the fissure and relieves the pain by relaxing the spasm of the sphincter.

The relief that some cases of bronchial asthma, intestinal colic and præcordial pain derive from diathermy is perhaps another example of the power of the current to relieve spasm. It is improbable that the lungs, heart or intestines are heated other than superficially, but the heating of the body wall, as well as the skin, and the continuous maintenance of the heat, may explain the success of diathermy after epithermy has failed.

Among the useful therapeutic properties of diathermy is that of elevating the body temperature when it is below the value which is normal for the individual. The artificial administration of the heat which the body cannot supply is followed by relief of malaise and discomfort, and the feeling of chilliness disappears. The body weight sometimes increases after a course of diathermic treatment in these cases of hypothermia. The symptoms which arise from certain maladies are aggravated if the body temperature is unduly low. The application of general diathermy will sometimes procure relief, even if the site of the disease is not directly included in the treatment.

Probably the most useful therapeutic property of diathermy is its power to aid the resolution of chronic inflammation, not only in cases where the cause, *e.g.*, trauma, has disappeared, but also in other cases where it is still active, viz., infection by bacteria. In congestion and unresolved inflammation, originally due to injury, the action of diathermy can be attributed to its power to accelerate the flow of blood and lymph through the affected parts.

When chronic inflammation is due to infection the application of diathermy is a valuable therapeutic aid because it induces active hyperæmia of the infected parts. By heating the infected tissues and the blood circulating through their capillaries it increases their power to rid themselves of the invading organisms. If the lethal temperature of the organism is lower than that of the tissues, as appears to be the case with the gonococcus, it is likely that diathermy exerts, in addition, a *direct* action on the bacteria themselves, distinct from the *indirect* action through the agency of the heated tissues.

It is probable, however, that the *indirect* action is more potent than the direct. Clinical experience shows that gonococcal infection can be brought to an end by raising the tissues to a temperature, the degree and duration of which are insufficient to kill cultures of the organism. There is also evidence that the streptococcus fæcalis, an organism which possesses a high lethal temperature, can be destroyed *in vivo*, *e.g.*, in the cervix uteri, by subjecting the living tissue to diathermy and raising it to a temperature much less high than that which will kill the organism in culture.

The power of diathermy to combat infection is seen in the treatment of late syphilitic infection of the central nervous system, particularly that which causes dementia paralytica. The entire body is subjected to diathermy, the so-called " therapeutic fever " being produced.

### CONTRA-INDICATIONS

It is unsafe to apply diathermy to regions from which hæmorrhage has recently occurred (or is likely to occur) if the cause of the bleeding is not under complete control. The active hyperæmia induced by diathermy may start the hæmorrhage afresh. It would therefore be unwise to apply the treatment to the lungs after recent hæmoptysis or to the stomach after hæmatemesis.

It was formerly thought that diathermy should not be administered to parts which are in a condition of *acute* inflammation. This belief has since been shown to be incorrect, for there are a number of diseases which can beneficially be treated in the acute stages and without risk. For example, in acute gonococcal epididymitis diathermy brings about rapid relief of pain and swelling. Puerperal septicæmia is another example ; the temperature in most cases soon reaches normal after general pelvic diathermy, and no complications occur. Other examples of the production of benefit in acute cases without the occurrence of harm are seen in the treatment of lobar pneumonia and carbuncle.

If pus is known to be enclosed and there are no channels by which it can drain away, it should be evacuated before diathermic treatment is commenced. This rule, however, is not invariable. Diathermy should not be administered during menstruation. Theoretically there is a risk of increasing the loss of blood. When, however, there is a continuous slight bleeding after the date when the menstruation should normally stop, there is no indication against to the application of diathermy to the pelvic organs. The treatment may procure the desired effect and stop the bleeding.

### RISKS

The main risk incurred in using the diathermic current is that of burning the tissue in immediate contact with the electrodes, viz., the skin or mucous membranes. If the patient's power of perceiving heat is not impaired, his sensation is a sufficient guide against the administration of an unsafe degree of heat. As long as heat alone is perceived there is no likelihood of causing burns. But when pain is felt the current must immediately be reduced. The pain caused by overheating must be distinguished from that which is sometimes felt during the application of diathermy in cases of referred pain. This is not difficult. Referred pain is felt in other parts as well as in the skin under the electrode. Whenever there is any uncertainty the electrodes should be removed—after stopping the current—and the skin examined.

When there is partial or complete anæsthesia of the skin the most thorough precautions must be taken in order to avoid burns. The labile method of application (p. 151) should be practised. In this method the operator's hand is in contact with the patient's skin and can detect the degree to which it is being heated. High degrees of heat should be avoided.

When general diathermy is being given and the dosage is large the risk of syncope should be borne in mind, especially during the first séance when the patient is likely to be nervous. In theory, there would be a risk of syncope if cases of hypopiesia were treated by general diathermy. The author, however, has administered this form of treatment to cases of hypopiesia, and no syncope or feeling of faintness occurred. Watch should always be kept, however, on the patient's appearance and pulse.

When diathermy is administered to the heart there is likewise a risk of syncope. During the initial treatment the current should be small and the séance short. At subsequent visits the increase of dosage should be gradual.

# CHAPTER XI

# DOSAGE IN DIATHERMOTHERAPY

## Administration of the Dose

It must always be remembered that the diathermic current does not immediately heat the tissues to the maximum degree which it is capable of doing. The rise of the temperature is comparatively slow. If the current is increased too quickly it can easily pass the maximum value consistent with safety without immediately causing pain or damage. For this reason it is always advisable to increase the current quite slowly to its maximum. As it would be inconvenient in practice to move the current regulator continuously with extreme slowness, the best plan is to move it gradually until heat is just perceptible, then let it stay in the same position until the heat is felt no longer to increase, then move it a little more, and again let it remain stationary for the same length of time, then move it still more, and so on, until any further increase of current causes pain or aching.

If these intervening periods of rest are omitted, the tissue in contact with the active electrode (skin or mucous membrane) will attain the maximum permissible temperature, *i.e.*, 115° F., before the underlying parts have had time to reach the temperature to which the current would have been able to heat them, had it been increased less quickly.

## Measurement of the Dose

Regarding the *measurement* of the dose, it must be remembered that the amperemeter is an insufficient guide to dosage. The instrument gives an approximate measure of the current that passes through the body, but does not tell how much of the current energy is transformed into heat in the body. The resistance of the tissues must also be known. If a narrow, highly resistant part of the body, such as the forearm, forms the path of the current it can soon be heated to the limit of toleration, yet the amperemeter may not indicate more than 0·7 ampere. On the other hand, if a broad region of low resistance, such as the abdomen, is traversed by the current the amperemeter may indicate 2 or 3 amperes although little heat is being generated. In the case of the forearm a comparatively weak current produces a high degree of heat, whereas in the abdomen a current which is three or four times as strong heats the tissues a slight degree only.

Some information regarding the dose could be calculated from the reading of the amperemeter if the resistance of the tissues along the path of the current were known. Too little, however, is known of the resistance (impedance) of different regions of the body under different conditions to currents of different frequencies to render calculation a guide to the degree of heat that a current can produce. Further, the amount of heat lost by convection cannot be ascertained.

The most accurate guide to the measurement of dosage is the thermometer or other heat-measuring instruments such as the thermo-couple. The internal temperature of the body as a whole can be measured, when *general* diathermy is given, by means of thermometers placed in the mouth or rectum. When *local* diathermy is given and the more superficial regions require the treatment, the temperature of the skin and of certain mucous membranes can be measured. The surface temperature gives a guide to that attained in the parts immediately underlying, and although it is only approximate, it is a more accurate guide than the reading of the amperemeter. In most regions of the body, however, it is difficult even to judge the degree to which the deeper parts are heated.

By reason of the inability, in most regions of the body, to measure other than surface temperatures, and the lack of accurate knowledge as to the heating of the deeper parts, it is usual, in everyday practice, to be content with the readings of the amperemeter, especially as the taking of surface temperatures is a tedious and time-consuming occupation. But the readings of the amperemeter are of little value unless the area of the electrodes is also known. What should be ascertained is not merely the *strength* of the current, but also its *density*.

The amperemeter is useful when the operator has become accustomed to his diathermic machine and has learnt the degree to which the skin of different regions can be heated when electrode of known surface area are employed. It must not be forgotten that machines differ, and although the amperemeter of one may indicate the same current as that of the amperemeter of another make, the region which is treated may not attain the same temperature with both machines, even though the size and situation of the electrodes are, as near as possible, identical.

In the light of the statements above as to the importance of knowing the temperature to which the diseased part is heated, if exact dosage is required, it will appear contradictory when it is learnt that the use of thermometers is not essential in the treatment of certain parts, viz., the rectum, cervix uteri and urethra—parts where thermometers can easily be introduced. But in the treatment of proctitis and urethritis the patient's sensation is a reliable guide. The parts just mentioned are heated, as will be learnt hereafter, to the maximum temperature that can be tolerated without pain of aching. This temperature, as already stated, is 115° F.

In addition to the temperature or, if it is not obtained, the density of the current, the remaining factor that should be known for the measurement of the dose is the length of time for which the current is passing. Its importance is obvious and it should always be measured.

## Dosage in Different Diseases and Morbid Conditions

What is known in regard to adequate or optimum dosage in diseases which respond to diathermic treatment has been learnt by clinical experience. Information is given in the ensuing chapters on diathermotherapy in diseases of the different systems of the body. It will not be out of place, however, to make some general observations on the subject, for although diathermy has been more widely used during the past decade than in previous years it is still too often employed as the last hope, after failure of other forms of treatment. For this reason there is much to be learnt in regard to its use in early or acute disease.

Speaking generally, it is erroneous to assume that the maximum degrees of diathermy are always the most effective in procuring therapeutic results. In the treatment of pain due, for example, to neuritis, greater relief may be obtained by milder degrees of diathermy over longer séances. In cases of early or acute inflammation due to infection there is the possibility of disseminating bacteria or their toxins if high degrees of diathermy are administered at the commencement of the treatment. Misadventure of this kind may occur, for example, if an acutely inflamed prostate gland is subjected to a high degree of diathermy.

In time to come it may be possible to give precise information in regard to the most effective dose of diathermy in the early stages of those diseases which are likely to respond to it when they are in a chronic condition. As a guide, however, it may be stated that in the early stages it is better to administer mild degrees of diathermy at first and lengthen the séances, say, to thirty minutes or longer.

# CHAPTER XII

## DIATHERMY IN THE TREATMENT OF SUBNORMAL TEMPERATURE AND DEFICIENT PHYSIOLOGICAL ACTIVITY (HYPOTHERMIA)

THE clinical condition about to be described does not appear to have been recognised as a definite malady, but it will be frequently encountered if looked for. The fact that it is frequently accompanied by other maladies directs the attention of the patient to the latter, and although he may complain of general malaise and a feeling of continuous chilliness, he attributes these symptoms to some local malady such as neuritis, rheumatism, etc. When no local malady is present and no organic disease, he complains of his inability to bear the cold and longs for the advent of warm weather.

Symptoms such as loss of appetite and dislike for food, dyspepsia, inability to sleep, depression, headache are frequently present. Women are frequent sufferers and some are poorly nourished.

Since the feeling of chilliness is the commonest symptom and a subnormal temperature the commonest sign, the name " general hypothermia " is suggested in order to connote the clinical condition above described.

The patients may be regarded as the subjects of deficient physiological activity, especially of the processes concerned in the production of heat and the maintenance of the normal temperature. For cases of this kind diathermy is a rational and successful form of treatment, in that it supplies the heat that the body cannot produce, thereby giving the thermogenetic mechanism a rest and enabling it in suitable cases to resume its normal activity.

When other maladies such as neuritis or fibrositis are present at the same time, their disappearance is not infrequently observed during a course of general diathermy and without local treatment. Cases, also, are seen in which local treatment is successful only after general diathermy.

The symptoms of "hypothermia" are frequently noted in old people, and a subnormal temperature is found. If there is no local or general malady they complain merely of their inability to keep warm during the winter months. General diathermy is no less gratefully received by them than by young patients. It is the treatment for old patients as well as cold patients.

It is a good plan, when undertaking the treatment of patients by physical methods, to inquire whether the symptoms above noted are present and measure the general temperature. If there are complaints of general chilliness and inability to keep warm, and particularly if the temperature is subnormal, a course of general diathermy should be commenced, and local treatment may be administered later if necessary.

### *Method of Application and Frequency of Treatment*

The method which the author usually adopts is to place the patient on a condenser couch, with a cylindrical electrode grasped by both hands. In the absence of a condenser couch the patient may recline on a sofa, and hold a cylindrical electrode in each hand. When possible, daily séances are held, each lasting from fifteen minutes to half an hour, until the oral temperature rises to normal, or 99° F. The temperature may be raised higher—to 100° F. if the patient loses the sensation of warmth before the next visit, and if there is no feeling of discomfort after the treatment. Occasionally there is a feeling of fatigue if a high temperature is attained. It is well to remember that a feeling of dizziness may be noted by the patient on getting off the couch after diathermy. In the author's experience this is not common, and—when it has occurred—short-lasting.

### *Results of Treatment*

Diathermy procures great benefit for the malady under consideration. The feeling of chilliness disappears. The patients lose their symptoms of lassitude, headache, dyspepsia, etc. They are able to sleep at night and a feeling of well-being is regained. Thin patients often gain in weight. As already mentioned, the symptoms of concomitant maladies may disappear without local treatment.

The results are long-lasting. A year or more elapses without return of symptoms. Some cases appear to have been permanently cured.

When the patient is the subject of chronic progressive disease the symptoms of continued chilliness do not respond so well to diathermy. The author has notes of a case of chronic Bright's disease in a gentleman of sixty who could never keep warm, summer or winter alike. This patient felt comfortable during the course of diathermy, but the relief was of short duration. Far different were the results obtained in this patient's sister, whose case was suitable for diathermy. The case is described below because the results appear to be permanent over a period of nearly eight years.

*Case* 1. The patient, a lady of 56, single, of very small stature, thin and fragile, had always felt the cold of the winter months acutely when in England, and, before the Great War, had spent these months abroad. During the winter of 1918–19 she suffered greatly from the cold and could not keep warm away from the fire. Her appetite failed and she ate very little and became still thinner. At night the feeling of cold prevented sleep.

Treatment by general diathermy was commenced on January 23rd, 1919. On this day her oral temperature was 96·6° F. Seventeen applications were made during a period of two months. The improvement of the patient's condition was remarkable. Her symptoms disappeared soon after the commencement of the diathermy and she remained comfortable, and free from cold.

A short course of treatment was given in the summer of 1920, a third in October and November, 1921. In November and December, 1922, four applications were given. On each of these occasions the symptoms had returned, but in slight degree only.

Each year after 1922 she spent the winter months abroad in a hot climate. In the autumn the symptoms of hypothermia returned but were always relieved by diathermy. Eventually she died of malignant disease in 1934 at the age of 70.

The following table shows the gradual rise of temperature during a course of diathermy in another case. The temperature before and after the applications was taken, also that at 7 a.m. and that at 10 p.m. Those at 7 a.m. and 10 p.m. were taken by the patient (who was accustomed to the task), and the same thermometer was used throughout. The figures represent the averages for each week.

| Period of treatment and observation. | Average temperature at 7 a.m. | Average temperature before diathermy. | Average temperature just after diathermy. | Average temperature at 10 p.m. | No. of applications of diathermy. |
|---|---|---|---|---|---|
| February 4–10 | — | 95·4 | 97·7 | — | 5 |
| February 11–17 | 96·2 | 96·5 | 98·3 | 96·7 | 5 |
| February 18–24 | 96·9 | 97·16 | 98·76 | 96·85 | 5 |
| February 25–March 1 | 96·7 | 97·3 | 98·8 | 96·9 | 4 |
| March 9–19 | 97·1 | 97·2 | 98·76 | 97·37 | 5 |
| March 20–25 | 97·3 | — | — | 97·3 | — |
| March 27–April 1 | 97·0 | — | — | 97·0 | — |
| April 2–8 | 98 | — | — | 98·1 | — |

*Case* 2. The patient in whom the temperatures noted above were taken was a lady of 40 and was sent to the writer for treatment of brachial neuritis. She complained, in addition, of general fatigue, cold (which kept her awake at night) and depression. These additional symptoms had been of much longer duration than the pain. General diathermy soon produced improvement of the patient's condition. The absence of the feeling of cold during the night was noticed first, and sleep was readily obtained. Appetite returned and fatigue disappeared. She gained 3 lbs. in weight in seventeen days.

In this case the pain due to the neuritis did not disappear during general diathermy, but it was quickly abolished when local diathermy was given in addition. The patient wrote six months later to say that she felt perfectly well.

The results obtained in the next case show the benefit that may be derived from general diathermy even though the local malady may be incurable.

*Case* 3. The patient, a girl of 19, was sent for treatment of a condition of " chilblain circulation " in her hands and feet. Her hands and wrists, feet and ankles were swollen, dusky blue and cold. Physical examination elsewhere showed nothing abnormal. She was thin, and complained of feeling always cold. In manner she was dull and morose. Diathermy was applied and the temperature of the whole body raised. This treatment had no effect on the swelling of the extremities, but the general health of the patient improved greatly. Her appetite increased and she gained weight, and colour reappeared in her cheeks. According to the account of her sister, with whom she was living, she became active and cheerful and worried no longer about her local condition.

The importance of the recognition of hypothermia in patients who are the subjects of other maladies is shown in the following two cases. Both were treated by general diathermy. In one the local malady—a painful scar—received no treatment. In the other—a case of severe neuralgia in the lower limbs—the latter parts were included in the diathermy, but the treatment was not localised to the painful areas.

*Case* 4. The patient, a girl of 23, had undergone an operation three months previously for removal of her gall bladder. During convalescence she developed pain and tenderness in and around the scar. She was sent to the writer for treatment of the pain. She was thin and morose in appearance and complained of chilliness and depression—a condition which she said was always present when she spent the winter in England. She said that she could not bear the slightest pressure on the site of the operation and was positive that no treatment would do her any good. In these circumstances no local treatment was given. General diathermy was administered on the condenser couch. When the patient felt the sensation of cold disappearing and the development of warmth her expression changed. She remarked that she had never felt warm since the beginning of autumn. (The treatment was commenced on November 12th, 1923.) During the course of the diathermy she became cheerful, and took an interest in her occupations. The scar retained some tenderness on pressure but ceased to be a source of trouble.

*Case* 5. The patient, a gentleman of 39, complained of severe pain in his lower limbs. Seven weeks previously he had suffered from an attack of tonsillitis. He said that he had had much pain in his throat and considerable swelling, but no rise of temperature. As the tonsillitis subsided pain developed in his waist and then in his hands. It lasted ten days and then appeared in his lower limbs, where it persisted. It became very severe. It occurred in bouts, usually between 1 and 2 p.m. and during the night. Sleep was impossible, and the patient said that he paced up and down his room during the night until nearly morning, when he fell asleep from exhaustion. By reason of his history, that he had returned (in January, 1923) to England after ten years' residence in India and had felt the cold of the English winter acutely, it was decided to administer general diathermy. The first treatment was given on November 14th, 1923. Electrodes were applied to the soles and the current was directed along the lower extremities for forty-five minutes. The same night the patient slept continuously and was almost free from pain when he came for his next treatment. Three treatments alone were given because the patient had to leave London. His pain had not disappeared entirely before leaving, but was only slight. A communication received at a later date showed that the patient had resumed his occupation, the pain being only slight and occasional.

# CHAPTER XIII

# DIATHERMY IN THE TREATMENT OF DISEASES PECULIAR TO MEN

## Therapeutic Field

In the treatment of certain infective diseases of the organs peculiar to the male sex, diathermy is able to render valuable service. Almost all the writer's experience has been gained in the treatment of cases which had resisted other therapeutic measures. In the major number the infection was gonococcal. In some the infecting organisms were streptococci, staphylococci, diphtheroid or coliform bacilli. In others the nature of the infection was not ascertained.

The most striking evidence of the influence of diathermy on the infected prostate and vesicles is seen in the disappearance of metastatic complications—when they are present. When they are absent there is clinical and bacteriological evidence to show that diathermy can render service of value in the treatment of the primarily infected foci. In the treatment of gonococcal epididymitis diathermy may well be regarded as the most effective therapeutic agent we possess. In senile enlargement of the prostate, diathermy, while exerting no therapeutic action on new glandular or fibrous tissue, is able to relieve any existing congestion or inflammation and may thereby lessen the obstruction to the outflow of urine.

## DIATHERMIC TREATMENT OF PROSTATITIS AND VESICULITIS

### Method of Applying Diathermy

In addition to the generator, two electrodes are required. One is the *active*, and the other the *directing* electrode. The active electrode is introduced into the rectum. The directing electrode is applied to the exterior of the pelvic region.

**Active Electrodes.** Two types of active electrode are illustrated in Figs. 77 and 78. Each consists of a metal end-piece which is attached to an ebonite handle. An ebonite ring is secured around the handle at a distance of 3·5 in. from the free extremity of the end-piece.

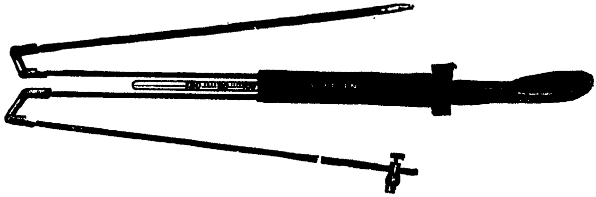

FIG. 77.—Active Electrode for Treatment of Prostate and Vesicles by Diathermy (*via* Rectal Route).

The electrode (Fig. 77) is channelled for the introduction of a thermometer. A couple of hinged metal rods are attached to the handle. They are in electrical connection with the end-piece. They can be straightened or bent to any angle. A detachable terminal can be fixed to the end of either rod. Before the electrode is used, each rod is enclosed, except at its free end, in a loosely fitting rubber tube. The metal end-piece is flattened on the surface which is to come in contact with the rectal wall behind the prostate.

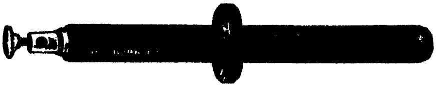

FIG. 78.—Another Type of Active Electrode for Treatment of Prostate and Vesicles by Diathermy (*via* Rectal Route).

The electrode illustrated in Fig. 78 is solid. The metal end-piece is circular in section and rounded at its free end. A terminal is fixed to the end of the handle.

Other types of active electrode also are used. One was devised by Stebbing for introduction into the prostate by way of the urethra (Fig. 79). It contains a thermometer. Some German workers employ an electrode, of which the metal end-piece can be opened or closed, somewhat like a fan. Before it is introduced into the rectum the end-piece is closed. When it is in position the end-piece is opened by turning a dial on the handle of the electrode.

In their original investigations the writer and C. A. Robinson employed a simple zinc rod as an active rectal electrode and it seemed to be as efficient as the more elaborate instrument now used. It should be noted, however, that if the electrode is made entirely of metal the lowermost end of the rectum and the anal canal will also be subjected to diathermy. This causes discomfort to some patients.

The passage of a urethral electrode, like that illustrated in Fig. 79, is disagreeable and its routine use is inadvisable, expecially if there is no certainty of absence of infection of the passage into which it is inserted.

**Directing Electrode.** This is a belt of thin sheet lead 2 in. in width (Fig. 80). It is long enough to encircle the widest part of the pelvic portion of the trunk, with its ends overlapping. The ends are secured by passing them through a strong wire loop and bending them back. To this loop a terminal is attached.

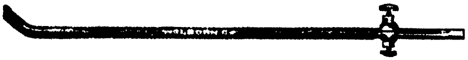

Fig. 79.—Stebbing's Electrode.

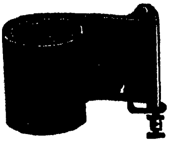

Fig. 80.—Belt Electrode.

**Application of the Electrodes.** With the patient on his side and his knees and hips flexed, the metal end-piece of the active electrode, previously warmed and anointed with boracic ointment, is passed into the rectum. If the patient is of average stature it can be passed for about 3·5 in. from the anus. In this position the ebonite ring is in contact with the anal orifice. The patient now turns on to his back and straightens his hips and knees. The belt electrode is passed around the trunk at the level of the pubes, the metal making contact with the bare skin. Its ends are passed through the wire loop and bent back so as to enable the belt to remain firmly in position.

If the electrode (Fig. 77) is used, the rods, previously enclosed in rubber tubes, are bent to a right angle and brought under the thighs. In this way the electrode is kept immovably in position. When the other electrode (Fig. 78) is used a towel is folded around its outer end in order to prevent the terminal and the uncovered metal end of the connecting cable from coming into contact with the skin of the thighs. The electrode is kept in position by the adducted thighs. The circuit is completed by connecting the terminals of the diathermic machine to the electrode.

**Regulation of the Current.** The current is started and slowly increased. A sensation of heat is felt in the rectum. Gradually the heat grows more intense. Eventually a sensation of pain, or a disagreeable ache, is felt. The current should then be reduced until the maximum degree of heat is felt without any pain or disagreeable sensation.

When the patient first becomes aware of the sensation of heat it is advisable to stay any further increase of the current until a minute or two have elapsed. The current may then be strengthened a little, and allowed to remain at the increased value for another minute or two before the next increase. The maximum degree of heat is attained in the rectal wall in contact with the metal end-piece of the electrode. If the current is increased too quickly the rectal wall will become painfully hot before sufficient time has elapsed for the prostate to rise in temperature more than a trifling amount. Slow increase of the current, stage by stage, in the manner stated, will enable the prostatic temperature to reach the highest value that the current will allow, without overheating the rectal wall.

The maximum temperature to which the rectal wall can be heated without pain is between 114° and 115° F. When the electrode illustrated in Fig. 77 is employed, the thermometer, correctly graduated, can only give the temperature of the metal end-piece and the inner surface of the rectal wall. Only on rare occasions has the writer been able to obtain temperatures as high as those stated, without causing pains or aches. Usually a temperature between 110° and 112° F. is the maximum that will produce the sensation of heat alone. The prostate is enclosed in an inelastic membrane and it is possible that higher degrees of heat may make the gland swell sufficiently to cause its compression. The painful aching sensation already referred to may be due to a compression of this kind.

During the treatment some patients feel the sensation of heat diminish after it has been at its maximum for a short time, in spite of the fact that the intensity of the current remains the same. Even if the maximum sensation of heat is not procured the patient may remark that he is feeling less heat than he perceived a short time before. Yet an inspection of the amperemeter shows that the current is not diminished. If the electrode is one that contains a thermometer it will be observed that a fall of temperature actually occurs. In all probability the fall is due to an increased loss of heat by convection, in consequence of the circulation of additional blood through the prostate as the gland grows hotter.

It is safer, in practice, to rely on the sensations of the patient rather than the reading of the thermometer. As already stated, the thermometer gives the temperature of the metal end-piece of the electrode and the inner surface of the rectal wall. There may be some loss of heat by conduction from the rectal wall to the metal around it. If so, there may be a higher temperature in the tissues deep to the rectum than that indicated by the thermometer.

The prostate cannot, of course, be heated uniformly when the electrode is in the rectum. The parts that are closest to the electrode will attain a higher temperature than those which are farthest away. C. A. Robinson found that a thermometer with its bulb in the cervical canal of a female patient indicated 108° F. when the rectal temperature was raised to 115° F. The active electrode was in the rectum and the directing electrode around the exterior of the trunk, the technique being identical with that described above. Since the relation of the prostate to the electrode in the rectum is approximately the same as that of the cervix to an electrode similarly placed, it is probable that a temperature of 108° F. would be reached in the centre of the prostate when the rectal temperature was 115° F.

*Comment on the Method.* The method above described has been criticised because the belt electrode completely encircles the pelvis, thereby providing paths for the current which do not pass through the prostate. It has been alleged that the current passing along these paths is "wasted." This is not the case. By heating the tissues behind the prostate it provides a hot "poultice" for the gland. If, however, the machine is one of small size it may not provide enough current to heat both the prostate and the tissues behind it to an adequate degree. If this is the case the belt electrode should be replaced by a rectangular electrode applied to the abdominal wall.

When the electrode is in position in the rectum an X-ray examination will show that it occupies a position about midway between those parts of the belt electrode on the anterior and posterior aspects of the trunk. As the bony sacrum offers a greater impedance than the soft tissues in front of the rectal electrode it may be concluded that a greater proportion of the current will pass through the prostate than behind it. If the patient is thin and his gluteal region poorly developed the insertion of a cushion between the pelvis and the couch, when he is recumbent, will enable the operator to depress the outer end of the rectal electrode, thereby bringing the prostate more towards the anterior aspect of the trunk. The electrode acts as a lever and the anus as its fulcrum.

**Duration and Frequency of Séances.** The treatment of prostatitis and vesiculitis should be conducted twice weekly. The rectal temperature should be maintained for twenty minutes at the degree which produces the maximum sensation of heat without pain or aching. The number of séances will be determined by the clinical and bacteriological findings. Generally speaking, eight séances constitute *one course* of treatment.

## TREATMENT OF GONOCOCCAL PROSTATITIS AND VESICULITIS

### Method

Details of the method of subjecting the prostate and vesicles have already been described. As already stated, the rectal temperature should be maintained for twenty minutes at the degree which produces the maximum sensation of heat without pain or aching. Two séances should be held each week. No advantage seems to be gained by more frequent treatment. After one course of treatment, consisting of eight séances, a clinical and bacteriological examination should then be made. If physical signs of prostatitis or vesiculitis remain, or if gonococci are found, or if the general health is not fully restored, a second course of treatment should be administered. In some cases a third course may be necessary. Usually, those which have already undergone treatment by other methods before diathermy is commenced respond most rapidly.

If anterior urethritis is present at the commencement of the prostatitis it will be necessary to continue the applications of diathermy to the prostate until all evidence of the urethritis has disappeared. As long as urethritis is present there will be a risk of re-infection of the prostate.

### Results

The influence of diathermy on gonococcal prostatitis and vesiculitis is witnessed, as already stated, in cases where metastatic inflammation is present. A course of diathermic treatment of the prostate and vesicles will bring to an end such complications as arthritis, fibrositis, bursitis, etc., in spite of the fact that the diathermy is not administered to the joints themselves, or to the fibrous tissues or bursæ. The details of the original cases in which this action of diathermy was demonstrated were published in 1925 in a monograph by the author and C. A. Robinson.[1]

The disappearance of metastatic complications does not prove, however, that the prostate and vesicles have been freed from gonococcal infection. Additional evidence must be obtained before a correct conclusion can be reached as to the action of diathermy on the primary focal infection. In the monograph referred to above are given details of 22 cases of gonococcal arthritis in men who had been successfully treated by prostatic diathermy. In three of them a bacteriological examination was made of the prostatic secretion. In the first, the report, ten days after a course of diathermic treatment of the prostate and vesicles, was " some mucus and pus cells but no gonococci " (nine treatments had been given during one month). The second had received ten treatments during five weeks ; at the end of the course the secretion contained " mucus, some pus cells and degenerated epithelial cells, but no gonococci." The third case had had eight treatments during four weeks. At the end of the course the secretion was examined. No gonococci were found. A week later, and again, eight weeks after finishing the course, no secretion could be obtained. The patient reported again after eight months. No discharge could be obtained. The joints were free from pain.

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[1] " Treatment of Gonococcal Infection by Diathermy." (William Heinemann Ltd.)

The three above-mentioned cases were sent from a Special V.D. Centre where treatment by other methods had been tried without success. Most of the subsequent experience of the writer has also been obtained in the treatment of cases which previously had been under the care of urologists or specialists in venereal disease. In these cases there was no clinical evidence of anterior urethritis, but prostatitis or vesiculitis persisted in spite of treatment by massage or vaccines, and gonococci were found in the prostatic secretion. After diathermic treatment the examinations of the secretion failed to reveal the presence of gonococci. In the secretion from some of the patients, pus cells were found, as was the case with two of the three original patients. In some cases were found other organisms, such as staphylococci, streptococci, diphtheroid bacilli or coliform bacilli. The microscope therefore did not reveal a " clean picture." The pus cells may have been the consequence of secondary infection. But as long as they are found it cannot be said that they are *not* due to infection by gonococci. Even if bacteriological examinations made long after the treatment reveal the presence of pus cells, the fear of the presence of gonococci within the prostate will remain despite the repeated failure to discover these organisms.

In two of the earlier cases (which were in hospital patients) diathermy failed to free the prostatic secretion from gonococci, in spite of repeated treatment. These failures, however, are overshadowed by the success obtained in a large number of other cases. They must, nevertheless, be mentioned, and they render it unsafe to make a final or precise statement as to the power of diathermy to rid the prostate and vesicles of gonococci. It can without doubt succeed in some cases (and, in the writer's experience, the majority) after the failure of other forms of treatment. For this reason it merits more serious and systematic attention on the part of urologists and specialists in venereal disease.

### Effect of Diathermy on Secondary Infection

After infection of the prostate and vesicles by the gonococcus there is always a likelihood of infection by other organisms. This secondary infection may persist for lengthy periods, long after bacteriological examination has failed to reveal the presence of gonococci. Other organisms, such as streptococci, staphylococci, diphtheroid or coliform bacilli, may be found in the prostatic secretion. One or more of these kinds of organism may be responsible for the gleet that persists in some cases, not only after the failure to find gonococci, but also after the disappearance of subjective symptoms, metastatic complications and ill-health. Continuation of the diathermic treatment is frequently unsuccessful in abolishing the gleet. In course of time the gleet may disappear spontaneously. In the following case of prostatitis the bacteriological evidence of gonococcal infection was negative after diathermy and the patient regained full health, but a morning gleet persisted and courses of diathermy failed to remove it. The subsequent events are described below.

The patient (B. W.) acquired gonorrhœa in October, 1928. He was treated by irrigation and afterwards by massage. As gonococci were still found in the prostatic secretion he was referred to the writer for diathermy. This was administered in June, 1929. Nine séances were held. Gonococci were not found at the end of the course. A colourless gleety discharge persisted, however, and prostatic massage was practised by his own doctor. In February, 1930, the urine was found to contain numerous epithelial cells and a few pus cells : the prostatic secretion contained a few pus cells but no gonococci were found. As the gleet did not disappear a second course of diathermy was administered, but without success. In September, 1931, the prostatic secretion was found to contain pus cells, diphtheroid bacilli, staphylococci, but no gonococci. The patient still complained of gleet, but his general health had remained excellent since his first course of diathermy. A third course of diathermy was given but the gleet persisted. The writer did not see the patient again until four years had elapsed. In August, 1935, he stated that he had not noticed any gleet during the past two years. Recently, however, it had been observed that the urine first passed during each act of micturition was cloudy. On rectal examination the prostate was not tender on pressure and no induration was felt. The patient was instructed to irrigate the urethra. In October, 1935, Mr. Kenneth Walker examined him at the request of the writer. He explored the urethra with an acorn-headed bougie and found no infiltration or painful spot. The meatus was too tight for urethroscopy and it was not considered necessary to perform a preliminary meatotomy. He found the prostate and vesicles normal on palpation, without tenderness or induration. No discharge was expressed on massage. The urine passed after massage was free from threads. In the two-glass test one thread was found in the first glass; it consisted almost entirely of mucus with a few epithelial and pus cells. Mr. Kenneth Walker expressed the opinion that no further treatment was necessary and that if the patient desired to do so, he could marry.

In the following case, methods, other than the diathermic, had been tried in different places but gonococci were always found in the prostatic secretion, and a discharge from the urethra persisted for years. The patient, however, never suffered from arthritis or epididymitis. After diathermic treatment no gonococci were discovered, in spite of repeated search. The subsequent events seem to show that gonococcal infection had been eradicated, in spite of the persistence of the discharge for nine years after the commencement of the treatment. (The discharge still exists—June, 1936.)

The patient (E. L.) was first seen by the writer in February, 1927. He stated that he had acquired gonorrhœa in 1915 and that a discharge had persisted ever since, in spite of treatment. Dr. Roxburgh, who sent the case, had been giving treatment by irrigation and massage: scars were present in the urethra but otherwise the urethroscopic appearance seemed to be normal. The prostatic secretion, however, contained gonococci. Eight applications of diathermy to the prostate were made in February and March, 1927. They did not stop the discharge. Dr. Roxburgh then re-examined the prostatic secretion and found no gonococci. The organisms were found, however, in the urethra. Diathermy was continued during April, May and June, 1927. During this time it was administered to the anterior urethra and the prostate at the same time. The discharge lessened in amount but did not disappear. In August, 1927, the patient was examined by Dr. Johnston Abrahams at the suggestion of Dr. Roxburgh. The following were the findings. (1) Smear of the material obtained by massaging the anterior urethra on a Kollman's dilator showed numerous pus and epithelial cells, but no gonococci. (2) The secretion obtained by prostatic massage showed, after cultivation, no gonococci or other pathogenic organisms. (3) The deposit obtained by centrifuging the first 2 oz. of urine, passed after the prostate had been massaged, was seen under the microscope to contain numerous pus and epithelial cells; no gonococci were seen. Dr. Johnston Abrahams made the following conclusions. "The result of the tests suggests that gonococci are either absent or very difficult to find, but that there is a distinct inflammatory reaction still present in the anterior urethra, but not in the prostate." No more treatment was given until September, 1927. The patient said that the discharge was slight and occasional ; it occurred during the day, and a morning gleet persisted. In October, 1927, another fruitless search was made for gonococci. The patient then announced his intention to marry. Advice and precautions were given—but not adopted. The writer did not see him again before May, 1931. He stated that the discharge was still present, that he had two healthy children and that his wife was in perfect health. He had been suffering from lassitude and pains in his back and shoulders. These symptoms disappeared after a course of prostatic diathermy but the discharge persisted. He remained in good health until May, 1932, when the symptoms returned ; in addition he had been troubled by frequent nocturnal emissions. Prostatic diathermy restored the patient's general health as before ; in addition, the nocturnal emissions occurred only on rare occasions. In January, 1934, he stated that he had been in good health since his last treatment, although the discharge had not come to an end. He was again examined clinically and bacteriologically. Prostatitis and urethritis were found. Cultures of the discharge exhibited growths of diphtheroid bacilli alone. It was decided to administer a longer course of diathermic treatment to the prostate and to the urethra as well. This, however, was no more successful than the shorter courses. The patient visited the writer on two occasions in 1935 with the request for diathermic treatment in order to reduce the frequency of nocturnal emissions, a trouble which had always been alleviated by diathermy. His general health has remained good up to the present time (June, 1936).

## Secondary Infection by Pyogenic Organisms

The prostate may secondarily be infected by pus-producing organisms and abscesses may form. A case of this kind was sent to the writer by Mr. Sydney MacDonald with the suggestion that diathermic treatment might be given because abscesses had been reappearing from time to time in spite of other forms of treatment.

The patient (M. J.) stated that he had acquired gonorrhœa early in 1924 and epididymitis had followed. He had been treated by the customary measures, and at the end of the year had apparently been cured. In the summer of 1925 he had again observed a discharge. Cystitis had developed and a para-urethral abscess had formed. This had been opened. Abscesses afterwards had appeared in the prostate and discharged by way of the rectum. Others had continued to form.

Diathermic treatment was commenced in November, 1925. After the first séance he developed epididymitis. This soon disappeared after the application of diathermy to the painful epididymis. Diathermic treatment of the prostate was then resumed. Its effects were slow but striking. Although inflammatory swellings appeared from time to time they did not suppurate and eventually they ceased to develop. The discharge gradually lessened and finally disappeared, although threads of mucus persisted in the urine. A striking feature of this case was the maintenance of good general health and spirits during and after the diathermy, even when inflammation was still present. The health began to improve soon after diathermy was commenced and it did not retrogress. In May, 1926, Mr. Sydney MacDonald re-examined the patient and found no evidence of inflammation or gonococcal infection.

Five years later (in June, 1931) the patient reappeared and stated that he had been in good health until a few weeks before when he began to suffer from lassitude and depression. He complained of pain in the perinæum and a gleety discharge. On examination the prostate was found to be swollen and tender. The fluid obtained after massage contained pus cells, streptococci and staphylococci, but no gonococci were found. Diathermic treatment was resumed. The pain and ill-health disappeared, also the tenderness of the prostate. Morning gleet persisted, however, and further diathermic treatment did not bring it to an end.

This case was last seen by the writer in January, 1932. His health was good and he was free from all symptoms except occasional morning gleet.

### NON-GONOCOCCAL PROSTATITIS

Patients are encountered who complain of lassitude, mental depression and loss of vigour. They may have a sallow complexion and a toxic facies. Some complain, in addition, of pains in the back, limbs, or joints. On inquiry a past history of gonorrhœa is obtained, but the patients say they were cured of it, no discharge having been seen for one or more years, not even a morning gleet. In cases of this kind the prostate and vesicles should always be examined and an endeavour made to obtain some secretion by massage. The gland will commonly be found to be enlarged, softer than normal, and tender on pressure, perhaps unilaterally. The secretion, if obtained, will contain pus cells and various organisms, such as streptococci, staphylococci, diphtheroid bacilli or coliform organisms. Gonococci are not discovered. Patients of this kind are the subjects of toxæmia. The prostate or vesicles, or both, are the probable sources of the toxin. In the writer's experience diathermy can usually be relied on to restore health to the patients. The bacteriological picture, however, does not show much change. For this reason the prognosis, in regard to future attacks, must be guarded. One course of eight séances of treatment should be given and when it is complete the patients should be instructed to report after a month. After the expiry of this interval it may be found that their health has improved so considerably that a second course is unnecessary.

The three following cases may be taken in illustration.

(1) The patient (R. T.), aged 42, was under treatment by the writer for injury of his quadriceps femoris muscle. During the treatment he said that he had been " out of sorts " for some months, feeling depressed and unable to do bodily or mental work. His appendix had been removed because it had been suspected to be the cause of his ill-health, but he felt no better in consequence. Inquiry elicited the fact that he had had gonorrhœa three years before, but the patient said he had been cured and had noticed no discharge or gleet during the past two years. Rectal examination revealed tenderness and swelling of the prostate. A course of diathermic treatment of the prostate and vesicles was administered. The patient began to feel better during the course, and at the end he had regained his normal health. A month later he wrote to say that he was still feeling fit.

(2) The patient (A. E.), aged 39, consulted the writer in February, 1934. He said that he had been suffering from pains in his shoulders and ankles since 1929. The pains had persisted in spite of treatment at clinics and spas. Faulty teeth had been extracted and the tonsils removed. His general health had been poor. He made no reference to any past attack of gonorrhœa, but when the question was asked he said that although he had acquired the disease in 1919 he had been cured of it. He added that his prostate had been examined in Australia in 1929—the year in which he began to suffer from the pains. The gland had been treated by massage after the examination but no relief had been obtained.

After obtaining this history the prostate was palpated. It was found to be swollen and tender. It was subjected to diathermy, a course of eight treatments being given. The pain disappeared from the ankles and shoulders, and he was able to walk increasingly long distances without discomfort before the conclusion of the treatment. He commented on the improvement in his health and spirits.

In 1936 the pains returned but they were again relieved by prostatic diathermy.

(3) The patient (F. D.), aged 25, acquired gonorrhœa in October, 1924. On December 12th of the same year he came to the writer complaining of severe pain and swelling of the scrotum, from which he had suffered since December 5th. The scrotum and its contents were subjected to diathermy. Five applications were given during seven days. Relief was immediate and at the end of the week there was no pain and very little swelling. Further treatment of the prostate could not be given because the patient had to leave London.

The writer did not see the patient again until October, 1927. He stated that his prostate had been massaged in January, 1925. This treatment, he said, brought on a second attack of inflammation of the same testicle as that originally affected. He stated that diathermic treatment had been given and that all pain and discharge eventually disappeared. On the occasion of his second visit to the writer he requested treatment for "lumbago," which had been causing him severe pain. On examination, his prostate was found to be tender and swollen. After a course of diathermic treatment the lumbar pain disappeared and the patient regained his full health.

The patient returned on two occasions between 1928 and 1936 complaining of poor general health and rheumatic pains in different parts. On each occasion his prostate was examined before commencing treatment and found to be swollen and tender. After diathermic treatment the tenderness and pain disappeared and the patient regained his health and lost his symptoms.

Prior to his last visit his tonsils had been excised and unhealthy teeth extracted. The infection of these parts was evidently not responsible for his poor health and the rheumatism because they did not disappear before the prostate was subjected to diathermy.

It should be realised that symptoms of the kind already mentioned may be narrated by male patients from whom no past history of gonorrhœa is obtained. The main complaint is fatigue of body and depression of mind. Inquiry may elicit the present or recent existence of additional complaints, such as pain in the perinæum or symphysis pubis, or in the " saddle area " of the skin. These symptoms will direct the examiner's thoughts to the prostate. This gland should always be examined. If there is evidence, even slight, of inflammation or tenderness, the prostate and vesicles should be subjected to a course of diathermic treatment. It should not be omitted even if the general examination reveals focal infection elsewhere, and it is even more necessary when the patient's symptoms persist after removal of suspected teeth, infected tonsils, etc.

One of the most striking examples derived from diathermic treatment of the prostate in a case presenting none of the painful symptoms of prostatitis, is the following.

The patient (F. M.) consulted the writer in July, 1927. His age was 45. He stated that he had been losing his health and vigour since February, 1926. Of late he had been subject to bouts of fever, each lasting for a day or two. His urine had frequently been offensive, It had been examined and found to contain coliform bacilli. The treatment which had been prescribed by a physician and a urologist had failed to procure relief. He consulted the writer on the recommendation of the patient (M. J.) whose case was described above. Prostatic diathermy procured relief almost immediately. He had no further bouts of fever, and in August, 1927, he was able to do full work. In September, 1927, he had "rheumatic pains" and was confined to bed for three days. Diathermy was again administered to the prostate and the patient soon regained his health. In October, 1927, he complained for one day of pain in his right shoulder and abdomen. Another course of diathermic treatment was given. During November and December, 1927, he was "better in health than ever before." In January and in April, 1928, he had a "chill" lasting for one day. A course of diathermic treatment was administered after each "chill" and he was able to resume work after the first séance of each course. In August, 1928, the urine, which had long lost its offensive character, was examined. A few epithelial cells and leucocytes were seen, but no bacteria. The following month a catheter specimen was cultivated but no bacteria were grown. In January, 1930, he suffered for one day from "rheumatism." During 1930, 1931 and 1932 he received courses of treatment at his own request because he kept so fit in body and mind after diathermy. In January, 1933, he received his last course of treatment. In December, 1935, he wrote to say that his health had remained excellent since his last treatment.

The only organisms found in this case were coliform bacilli. There was no past history of gonococcal infection.

Lastly, it should not be forgotten that an infected prostate or vesicle may be the hidden culprit in patients whose symptoms and appearance are those of toxæmia and persist after applying treatment to other parts. The absence of symptoms pointing to prostatitis or vesiculitis and the inability to obtain a past history of gonorrhœa should not make a rectal examination unnecessary. The following is described as an illustration.

The patient (A. F. M.), aged 56, was brought to the writer by Dr. Moir (who kindly allowed the publication of the following particulars). The subject of the case had been in poor general health for a long time, complaining of depression and inability to work or take exercise without fatigue. He had received a general examination by a physician before he consulted Dr. Moir. Obsolete pulmonary tuberculosis was discovered but nothing was found to account for the symptoms of toxæmia and the presence of minute effusions of blood under the skin. The prostate gland, however, was not examined. This omission was afterwards rectified by Dr. Moir, whom the patient afterwards consulted. Prostatitis was discovered.

Diathermy was administered. Each application was preceded by prostatic massage which Dr. Moir applied. The patient began to regain his health during the course of treatment. After eight visits the prostate lost its tenderness and regained a normal size. His symptoms disappeared and his general health returned. Three months later it was learnt that the patient had maintained his health and increased in weight.

### DIATHERMY IN COMBINATION WITH MASSAGE

It has already been mentioned that pus cells and various bacteria can be regained from the prostate even after the application of diathermy to the gland has caused the disappearance of metastatic inflammation, toxæmia and symptoms of prostatitis. Diathermy is unable to eradicate non-gonococcal infection although it seems to have the power to render it quiescent for long periods. But at a later date it may again become active. It seems, therefore, that some additional form of treatment is advisable. It may take the form of massage. Of late the writer has been subjecting cases of prostatitis to diathermy in combination with massage, the last-mentioned being given immediately before the diathermy. The cases chosen were very chronic ones. The results of the combined treatment have been encouraging. Not only did the symptoms disappear, but the prostate regained its normal condition and the microscopic appearance of the secretion was a "clear picture." The following case is a good example.

The patient (G. E.), aged 44, gave a past history of gonorrhœa acquired about two years previously. There had been a recent return of discharge. When he consulted the writer the discharge had disappeared, but the patient had pain in his loins, was in poor health and had a "toxic" appearance. No gonococci were found but pus cells and other organisms were present. After a course of diathermic treatment he felt quite well. The prostate was not tender on pressure. The writer then asked Dr. Moir to examine his gland.

Dr. Moir thought that it was larger than normal. The fluid he obtained by massage was turbid and its examination under the microscope showed little difference from that already noted. A second course of diathermic treatment was commenced, each application of diathermy being preceded by massage. Eventually no pus cells and no bacteria were found. The same negative picture was observed one month after the treatment ceased, and again four months after.

### DIATHERMY IN GONOCOCCAL EPIDIDYMITIS AND ORCHITIS

#### Method of Application

Two electrodes are required. One of these is the rectal electrode already described. It is placed in the position needed for the application of diathermy to the prostate. The other electrode is applied to the scrotum.

One type of scrotal electrode is illustrated in Fig. 81. It is made of sheet lead. A piece measuring 3 in. by 4 in. is cut to the shape shown. Before it is applied to the scrotum it is bent along the line *ab* to make it assume the form of the letter U. The lowermost part of the scrotum occupies the bend of the U. The limbs of the U make contact with the anterior and posterior parts of the scrotum. The lateral portions of each limb can be bent round the lateral parts of the scrotum so as to meet or overlap each other and make uniform pressure and contact with the skin over the testis and epididymis.

Another type of scrotal electrode is illustrated in Fig. 82. It is easier to apply when the scrotum is not lax.

The rectal electrode is first introduced and maintained in position in the manner already described. The patient then lies on his back, with his thighs together and his scrotum supported on a pad covered with waterproof. Strips of lint, wrung out of hot salt solution—the latter being not less than 10 per cent. in strength—are applied to the scrotum so as to envelop it completely and form a pack at least ¼ in. thick. The lead sheet is now applied to the pack and bent so as to cover it and maintain its position with light and even pressure.

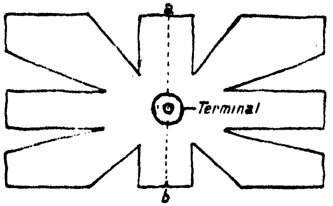

FIG. 81.—Electrode for applying Diathermy to Testis and Epididymis.

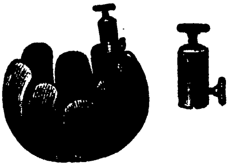

FIG. 82.—Scrotal Electrode used in applying Diathermy to Testis and Epididymis.

The current is started, and increased slowly until the patient perceives a sensation of warmth in the region of the neck of the scrotum. Its strength should be sufficient to produce comfortable heat in the scrotum and rectum without pain in either part. The current should be passed for twenty minutes.

By this method diathermy is administered, not only to the testis, epididymis and that part of the vas deferens which lies in the scrotum, but also the prostate, vesicles, posterior urethra and the parts which are in close relation to them. The reason for the inclusion of the prostate and vesicles is the likelihood of the presence of infection in these parts. Although they are more effectively treated when the electrode—other than the rectal—is the metal belt which is placed around the pelvic region of the trunk, there is gain of time by including the prostate and vesicles in the circuit and subjecting them to diathermy synchronously with the testis and epididymis. It is shown below that epididymitis and orchitis come to an end, under diathermic treatment, before the expiration of the minimum time that can be allowed for adequate treatment of the prostate and vesicles.

### Results in Gonococcal Epididymitis and Orchitis

Gonococcal infection of the testis and epididymis responds rapidly to diathermy. Pain is quickly abolished, some relief being obtained *during* the first treatment. Tenderness and swelling subside, and after the third treatment and the expiration of ten days there is no pain, no tenderness and no swelling save, in a certain proportion of cases, some thickening of the tail of the epididymis, but without tenderness on pressure. Inflammatory thickening of the skin of the scrotum disappears. It is rarely necessary to give a fourth treatment.

These rapid results were obtained in 35 out of a series of 37 cases.[1] The remaining 2 required more than four applications, but the final results were the same.

It is in the rapid relief of pain that diathermy is so efficient. In some of the cases which have been treated by the author and his co-workers the pain was severe enough to compel the use of sticks or crutches. The facility with which the patients were able to walk at the conclusion of the first treatment was striking.

After the signs and symptoms of inflammation have disappeared from the scrotum the application of diathermy to the prostate and vesicles should be continued. In place of the scrotal electrode the metal belt, previously described, should be employed and placed around the pelvic region of the trunk. The prostate and vesicles then are treated in the manner already described.

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[1] Details of these cases are given in the monograph mentioned in the footnote on p. 196.

The importance of including the primary focus in the treatment of metastatic infection is realised. Some authorities will maintain that infection of the scrotal contents is not metastatic but due to the spread of infection along the vas deferens. It is nevertheless a fact that the results, described above, of the application of diathermy to the scrotum can be obtained by limiting the treatment to the prostate and vesicles and excluding the scrotum. This has actually been demonstrated. It is better, however, in practice, to include the scrotum during the first three applications, because pain is more quickly relieved if this is done.

When treated by agents other than diathermy a period of three to six weeks elapses before gonococcal epididymitis and orchitis subside. It was in the treatment of cases of the longest duration that diathermy was first tried. By reason of the good results, Dr. Roxburgh, who was at that time assistant M.O. to the V.D. department attached to St. Bartholomew's Hospital, sent further cases directly to the author's department for diathermy without a preliminary trial of other methods. Anterior urethritis, if present, was treated in the V.D. department.

Diathermy should receive serious trial in cases as soon after the onset of symptoms as possible. By reason of its power in aiding resolution of inflammation the thickening of the globus minor, which so often persists after swelling has disappeared elsewhere, might not occur. Occlusion of the canal would then be prevented. In cases of long duration diathermy is able to abolish the pain, tenderness and swelling, but the thickening of the tail of the epididymis remains and further applications of the treatment do not seem able to cause its disappearance.

## Application of Diathermy to the Vas Deferens

That part of the vas which lies in the scrotum is included in the treatment when diathermy is applied to the testis and epididymis. Occasionally there is an inflammatory swelling in the region of the inguinal canal. This is apparently due to inflammation of the vas. When this swelling is found it should be subjected to diathermy by way of a plate electrode large enough to cover it. The treatment should be given after diathermy is applied to the contents of the scrotum, the rectal electrode remaining in position.

### TREATMENT OF GONOCOCCAL URETHRITIS BY DIATHERMY

In the early days of diathermy the treatment of anterior urethritis was attempted by workers on the Continent (Boerner, Santos, Schmidt). A hollow metal tube was passed into the urethra. This constituted the active electrode. The circuit was completed by plate electrodes which were placed on the thighs, perinæum and sacrum. A thermometer was placed in the tube and temperatures of 44° to 45° C. were obtained. Some good results were claimed. It is difficult, by this method, to obtain a uniform degree of heating of the urethra, and burns were sometimes produced.

Attempts were afterwards made to obtain a more even heating of the urethra. There is no method of applying a uniform and high degree of diathermy to the entire urethra in one operation. Apart from this the introduction of an electrode into an infected urethra is not without risk.

Other methods have been tried in the electrical department of St. Bartholomew's Hospital. In one, an electrode was applied to the end of the penis, and the circuit was completed by a rectal electrode. In a second, two electrodes were applied respectively to the dorsal and ventral aspects of the penis. These methods were used singly and in combination, and in some cases the posterior urethra was treated in addition by the method utilised for subjecting the prostate to diathermy. In a third method the penis was turned upwards and backwards so as to lie in contact with the abdominal wall. A padded metal electrode was applied to its ventral aspect, and the other electrode was placed in the rectum. More recently a fourth method was devised by Dr. C. A. Robinson. The penis was turned downwards and backwards so as to lie in contact with the perinæum and between the testicles. A padded metal electrode was applied so as to cover the perinæum and the dorsal aspect of the penis. This electrode was 1 in. wide and long enough to extend from a point a little below the lower border of the symphysis pubis to a point 2·5 in. from the anus. A second electrode was placed in the rectum for 3·5 in. By this method there is more likelihood of heating the three portions of the urethra simultaneously. By the following method they can be heated *successively*. The posterior portion is treated when the prostate is subjected to diathermy. The membranous portion can be treated by applying a plate electrode to the perinæum, the other electrode being in the rectum against the prostate. To treat the anterior portion the penis may be placed between a couple of long narrow plate electrodes.

Each of the methods above described has the advantage that the possible risk of introducing an electrode into an inflamed urethra is averted. The treatment of the entire urethra by diathermy is a tedious and time-consuming procedure. If it could be relied on to abort the infection with the rapidity seen when gonococcal urethritis in women is treated by diathermy it would be worth the time and trouble. But although posterior urethritis is effectively treated when the prostate is subjected to diathermy, anterior urethritis seems to respond to diathermy no more quickly than it does when the customary methods are employed. In one case of infection of the anterior urethra the penis was included between a pair of electrodes and heated to a temperature of 114° F. for *one hour*. This treatment was repeated on four occasions. In spite of the high temperature and its long duration gonococci were recovered from the anterior urethra.[1]

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[1] The failure of diathermy in anterior urethritis in men and its success in urethritis in women calls for comment. The uniform heating of the urethra in women to 115° F. by diathermy is easy in comparison with a similar task in men. But there is a more likely reason for the lack of success in men. In the tissues the gonococcus grows most vigorously at temperatures between 93° and 98° F. It is not generally known that the temperature of the anterior urethra in men is no higher than 93° F. This fact was ascertained by C. A. Robinson. On the other hand, the urethral temperature in women is 99·2° F. It will be realised, then, that the

## DIATHERMY IN SENILE ENLARGEMENT OF THE PROSTATE

The writer has employed diathermy in the treatment of a number of cases of enlargement of the prostate in elderly patients who complained of undue frequency in passing urine, with or without difficulty in its passage. Many of them derived some degree of relief. A few were completely relieved at the end of the treatment, while others derived no benefit.

In the cases in which diathermy procured relief it is probable that the frequency and obstruction were caused by enlargement due to congestion and perhaps also to mild inflammation of the gland. The treatment could be expected to relieve pathological conditions of this kind. But it cannot be expected to reduce adenoma, glandular enlargement or fibrous tissue.

When the question arises of the advisability of diathermic treatment for patients who complain of the above-mentioned symptoms, it should be decided by rectal examination. If the prostate is felt to be firm or hard in consistency it is unlikely that diathermy will be of use. On the other hand, if the gland is relatively soft, giving the palpating finger a sensation not unlike that which it would get on pressing raw meat, it may be assumed that some degree of congestion or inflammation is present. In cases of this kind diathermic treatment may give relief.

gonococcus can grow more vigorously in the male than in the female urethra, and it seems that the elevation of the temperature to 115° F. has a lethal effect on the less vigorous growth. But this is not the entire explanation. There is sufficient clinical evidence to show that diathermy has the power to terminate inflammation, due to gonococci, in regions where it cannot procure temperatures which have been shown by experiments *in vitro* to be lethal for these organisms. It must be concluded, therefore, that the main action of diathermy on gonococcal infection is not solely a *direct* one *on the organisms themselves*, but rather an *indirect* one *on the infected tissues and on the blood passing through them*. Why this indirect action is not effective in cases of anterior urethritis in men remains to be discovered.

## CHAPTER XIV

# MEDICAL DIATHERMY IN GYNÆCOLOGY

BY
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## A. PELVIC INFECTION

### I. PRELIMINARY OBSERVATIONS

THE great bulk of pelvic infection in women results from, and, in chronic cases, is kept active by, infection spreading from the cervix.

It is thus of supreme importance to possess a means by which cervical infection can be eradicated. Such a means is intra-pelvic diathermy.

In the following pages an account is given of cervical infection, the various syndromes and maladies to which it gives rise and the technique employed in treating them.

It may be remarked at the outset that although these syndromes have been well known for a long time, the result of many years' work with intra-pelvic diathermy has been to draw special attention to the importance of cervical infection in their etiology and thus to demonstrate a close relationship between them, however they may differ from one another in their general features. To give an example, which will be treated at greater length later, both the syndrome of toxic backache, so common in women after child-birth or miscarriage, and also the syndrome of chronic infective polyarthritis are associated with cervicitis. This perhaps is common knowledge; but the important fact which has emerged from work with diathermy is that the former is frequently the herald of the latter, the common factor running through them both being the infected cervix.

A detailed account will be given of most of these syndromes and emphasis laid throughout on the clinical aspect of the subject, because success with diathermy depends not on a profound knowledge of instruments and technique, but on the proper selection of cases for treatment.

**Structure of the Cervix.** The cervix is composed largely of glandular tissues consisting of branched tubules lined by columnar epithelium embedded in a fibro-muscular framework. There is no capsule and the ramifications of the glands extend almost into the cellular tissues of the broad ligament and other fibrous structures in the neighbourhood. The lymphatics open freely into those of the surrounding fibrous tissues and of the uterus.

**Mode of Spread of Infection.** The spread of infection, gonorrhœal or otherwise, is by the lymphatics and intercellular spaces of the tissues surrounding the acini of the glands. The toxins, especially perhaps the gonotoxin, have an extremely irritating effect upon the cells and produce an excess of secretion mixed with leucocytes.

The secretions of the cervical glands are discharged into a canal passing down its centre. This canal is not lined by stratified epithelium but by the same type of cell as composes the rest of the glandular tissue.

**Insensibility of the Cervix.** The cervix is insensitive, so that pain is not experienced unless the surrounding fibrous structures are inflamed. The pain is then usually referred to the lower back and abdominal walls, with perhaps only some sense of discomfort within the lower abdomen.

**Inferences.** It follows from these facts that infections of the cervix are especially likely to cause toxæmia. This occurs if the infection reaches a short distance from the central canal. It follows also that the patient may be quite free from pain until this occurs. This accounts for the frequency with which referred pain and toxæmia are associated and for the fact that one without the other is not common.

It will also be apparent that the application of antiseptics to the cervical canal is not likely to be successful, especially if they cause coagulation of the secretion. An effectual remedy must be able to exert its influence directly or indirectly on the periphery of the glandular ramifications as well as on the centre of the gland.

The periphery of the cervix can be heated by diathermy to a temperature several degress above the normal without damage to the cells in immediate contact with the electrode.

**Effects of Diathermy.** Heating the infected tissues has a two-fold effect :—

(1) It has a lethal effect, or, short of this, an inhibiting effect on organisms. This may be important in the case of gonorrhœa, since the lethal temperature of gonococci is low, but there is probably no direct action on other organisms.

(2) It raises the bactericidal power of serum and leucocytes and increases their quantity in a given area.

**Local Signs of Cervical Infection.** Digital examination cannot be relied upon for a diagnosis of cervical infection. The cervix must be inspected.

Excoriation of the cervix around the margin of the external os is the earliest visible sign of cervical infection and is produced by the macerating effect of a pathological discharge. This may occur for only a small distance, producing a bright red, somewhat granular rim to the os. The area may be more widespread and there is then a patch on either lip of the cervix of considerable size, more often on the posterior lip, though it may extend all round the os.

In cases in which the denudation is severe or long-lasting the columnar epithelium of the cervical canal grows down over the raw area, so that glands lined by this epithelium open on to the vaginal surface of the cervix. There is then produced one form of *erosion*, which is a patch made up of these down-growing columnar cells, together with islets of squamous epithelium and perhaps granulation tissue.

A word or two of explanation is necessary here on the significance of an erosion. An erosion in itself is a harmless lesion. It is frequently produced by cervical infection, as described above, but it also often persists long after cervical infection has disappeared. Further, congenital erosions are quite common; they are due to failure of the columnar epithelium of the cervical canal to retreat back to its normal limit (*i.e.*, the external os) after intra-uterine life.

For these reasons an erosion (as contrasted with an excoriation) is best ignored, both in seeking for local signs of infection and in estimating the results of treatment. The narrow, bright red rim round the os, showing that excoriation is beginning, is the most reliable local sign.

There is nothing to be gained by treating an erosion—it is the infection in the deeper parts of the cervix that requires to be eradicated.

**Relapse.** Relapse will occur unless complete freedom from infection has been achieved. For the reasons given above this is most difficult to estimate. In some cases the squamous epithelium grows over the denuded area and a smooth membrane is formed right up to the margins of the external os. Even then deeper infection may still be present. In other cases an erosion still persists, though the patient's general condition may have improved long ago. Here there is the uncertainty of knowing when to stop treatment.

For these reasons I make it a rule to have a complete follow-up of these cases, *i.e.*, to see them again every month for three or four months. Their subsequent histories form the most reliable criterion of cure.

**Treatment of the Cervix with Diathermy.** There are two distinct aims in treating cervicitis :—

(1) The removal of the toxæmia resulting from it. The various manifestations of this toxæmia will be described later.

(2) The removal of infection from the cervix.

The former of these is almost invariably accomplished within a month or two by intra-pelvic heating given twice weekly with a vaginal electrode (see p. 221).

Such a result is, however, only temporary, and relapse will certainly occur if the cervical infection is not subsequently attacked. This is done by the application of diathermy to the cervical canal, the length of time over which treatment must be carried out varying within wide limits.

The treatment of the toxæmia is undertaken first for the following reason. The toxæmia is accompanied by certain symptoms, notably abdominal pain and backache, and by certain signs, chief of which are some tenderness in either fornix and an enlarged and tender uterus. If these signs are not removed before intra-cervical diathermy is begun the pain will be aggravated and the patient made worse, at least temporarily. She may complain of vomiting and have some pyrexia and malaise and be confined to bed. Since most of these women belong to the out-patient class this is not desirable.

In some cases the toxæmia can be relieved in four treatments during a fortnight by the vaginal electrode. As a rule eight treatments spread over a month are required. Somewhat uncommonly two months are needed.

Four subsequent intra-cervical treatments will sometimes produce a return to the normal, but in most cases a month or two months of bi-weekly treatments is required, whilst in a comparatively small number prolonged treatment is necessary, sometimes lasting a whole year before the cervix is perfectly normal.

## II. DESCRIPTION OF THE INSTRUMENTS AND METHOD USED FOR CERVICAL AND URETHRAL TREATMENT

This method was first elaborated and used in 1919 in the electrical department of St. Bartholomew's Hospital. The department was then, as it is now, under the direction of Dr. E. P. Cumberbatch, and the writer was at that time engaged in treating cervicitis and cervical erosions by direct current applications.

Dr. Cumberbatch had already made, in 1913, the observation that heating gonococcal joints with diathermy caused a rapid subsidence of the inflammation and that this did not occur with other forms of arthritis. It was known that gonococci in culture were easily destroyed by comparatively slight rises of temperature. The attempt was therefore made to destroy the organisms by raising the infected tissues to the highest temperature possible without injury.

Under the conditions where it was desirable for this to be done, namely, as out-patients and without an anæsthetic, the limit of temperature reached is set, not only by the fact that no destruction of tissue must occur, but also that pain must not be produced.

The temperature reached in the urethra cannot therefore exceed 115° F., as this is the point at which the sensation of heat changes to pain. This does not apply to the cervix, which is sufficiently insensitive for coagulation by heat to occur without any sensation of pain.

Pain is part of a mechanism which prevents injury, and it may be assumed that no injurious effects are produced by heat on the cells until the temperature producing pain is reached. After that the phenomena of inflammation occur. If the female urethra is heated for long periods up to 115° F. no sign of inflammation is apparent next day. If the temperature, however, is raised to 116° F. for a few minutes signs of inflammation appear the next day, causing some pain on micturition which may last a day or two.

The chemical changes which occur in tissues, serum and leucocytes, constituting resistance to bacterial invasion, are accelerated by heat just as all chemical changes are. Thus the greatest temperature which can be reached without damage to the tissues is probably the optimum. This is 115° F., and actually it leaves a margin of safety of 16° F., since alteration in constitution of tissue proteins does not occur below 131°F.

There are two factors concerned in therapeutic heating, namely, the temperature to which the tissues are raised and the time of application. It does not follow that heating for a long time will produce greater results than for a short time. In practice, I have found that ten minutes is the most effectual duration for a treatment.

As has already been mentioned, the lethal effect on the infecting organism is not the only factor concerned. Cervicitis is cured with consequent beneficial results on an associated arthritis in cases which are not gonococcal in origin. It has to be assumed that here the main effect is a raising of resistance to infection. It is interesting that gonococci cease to exist in the body after a time of application of heat which is shorter than that required for killing them *in vitro* by the same temperature. The growth of the gonococcus takes place between 77° and 100·4° F. The optimum temperature is between 95° and 98·6° F. Exposure to 109° F. for seventy-six minutes, to 111·2° F. for fifty-four minutes or to 113° F. for thirty-seven minutes kills the organisms. Many analagous instances can be drawn from pharmacology; for instance drugs such as the arsphenamine compounds and emetine only produce their specific effects *in vivo* or produce them much more rapidly and in smaller doses than *in vitro.*

The diathermy current is applied by the introduction into the urethra and cervix of metal active electrodes of the writer's own design. The circuit is completed by a flexible metal belt (indifferent electrode) applied round the pelvis in such a way that the active electrodes are in each case nearly in the centre of the encircling belt. This belt electrode is due in the first place to Kowarschik of Vienna. The active electrodes are as nearly as possible in the same transverse plane as the belt in order that the current may come off uniformly throughout the length of the electrode inserted.

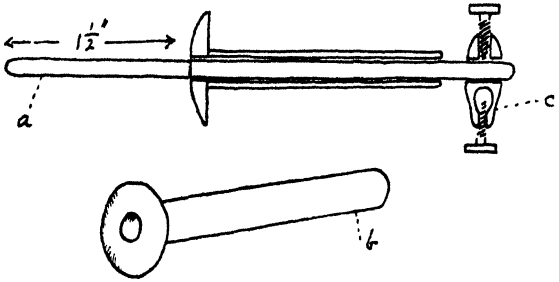

Fig. 83.—Urethral Electrode.

**The Belt Electrode.** This is a strip of lead 2½ in. wide and thin enough to be easily moulded to the contours of the body. It is fastened by passing its free ends through an elongated loop of stout brass wire and bending them back on themselves. One side of the elongated loop is prolonged somewhat and has a screw terminal soldered to it for the attachment of the cable to one terminal of the diathermy machine.

**The Urethral Electrode.** This consists of three parts:—

(1) A metal rod 5·5 mm. in diameter (S.W.G. No. 4) and 4 in. long (Fig. 83, *a*). It is marked by a line 1½ in. from one of its extremities.

(2) A vulcanite tube (Fig. 83, *b*) with a perforated vulcanite disc fastened to one end. The internal diameter of the tube allows it to slide easily over the metal rod.

(3) A binding screw and screw terminal combined (Fig. 83, *c*).

Before the tube is slipped over the metal rod the binding screw is fastened near one end of the rod in such a position that when the end of the vulcanite tube opposite to that to which the disc is attached abuts on it the other end of the tube, or rather the face of the disc, is at the mark 1½ in. from the end of the metal rod.

**The Cervical Electrode.** This consists of a metal rod of the same diameter as the urethral electrode. It is conveniently made of soft metal such as lead or soft copper so that the end to be inserted into the cervix can be bent to a suitable angle at the time of insertion. It is long enough to project 3 or 4 in. beyond the speculum when in place. A piece of rubber drainage tube sliding easily along the electrode is provided and a combined binding screw and screw terminal is also essential.

**The Stand.** A suitable stand for supporting the electrodes (Fig. 84) is necessary. It consists of a circular metal base (*d*) supporting an upright pillar (*e*) on a piece of vulcanite (*f*), which thus insulates the pillar from the base. A spring clip (*g*) slides on the pillar and thus provides a vertical adjustment. It has attached to it a horizontal metal arm (*h*) carrying a short tube (*k*) rotating about it and capable of being fastened in any position by a binding screw (*m*). To this short tube is fixed a screw terminal (*n*). A piece of soft copper wire connects the terminals of the stand and of the electrodes. A binding screw (*p*) is fastened to the base of the pillar and serves for the attachment of one of the cables of the diathermy machine.

**Technique of the Applications.** The patient lies on her back with her shoulders low, her head slightly raised and a small sandbag under the buttocks. The belt electrode is applied round the pelvis at a level about midway between the crest of the ilium and the great trochanter. The urethral electrode is introduced until the vulcanite disc is pressed against the external meatus. There is then 1½ in. inserted.

The stand is placed between the slightly abducted thighs, and the electrode and stand are connected by the piece of copper wire passing between their respective terminals.

One terminal of the diathermy machine is connected to the belt and the other to the stand. The current is switched on and increased gradually until the patient says that the sensation of pain is just beginning. The point where the sensation of heat changes to pain can be very accurately determined. Having obtained this point the amount of current is reduced slightly until the patient says that the sensation is that of great heat. The application lasts ten minutes.

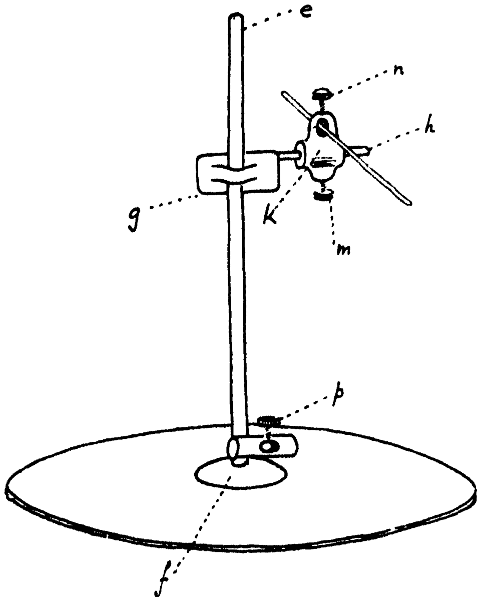

FIG. 84.—Stand for supporting the Urethral or Cervical Electrode.

Having removed the urethral electrode the speculum is introduced into the vagina and the cervix exposed. The cervical electrode is then introduced so that, as a rule, $\frac{3}{4}$ in. of it is inserted into the canal. The rubber sheath is then slipped over the electrode until it is in contact with the cervix. The cervical electrode is connected to the stand in the same way as the urethral, and the current switched on. If ¾ in. of electrode has been introduced, the current is increased up to half the amount used for the urethra. This is the usual procedure, but in any case the amount of current applied to the insensitive cervix is the same as that applied to the sensitive urethra in proportion to the relative amount of electrode introduced.

The duration of the cervical treatment is ten minutes. Treatments are usually given twice weekly.

### III. DESCRIPTION OF THE INSTRUMENTS AND METHOD USED FOR GENERAL HEATING OF THE PELVIC CONTENTS

It has already been explained that untoward symptoms develop if the foregoing methods are applied without some preliminary treatment with a vaginal electrode designed to produce general heating of the pelvic contents.

With a knowledge of the effects produced by heating the prostate in cases of prostatitis I determined to use a similar method for female cases. As a result the vaginal electrode now to be described came into use.

The object being to obtain a rise of temperature of the pelvic contents as widespread as possible from an electrode placed roughly in the centre of the pelvis, the metallic contact of an intra-vaginal electrode must be as large as can conveniently be made and the indifferent electrode must form a circle of which the vaginal electrode is the centre.

The same belt electrode as that described for the urethral and cervical treatment is used. The vaginal electrode (Fig. 85) consists of two parts :—

(1) A short metal cylinder (*a*) 1½ in. long and 1 in. in diameter with one end rounded. In longitudinal section the rounded end of the cylinder forms a semicircle. The sides of the cylindrical portion meet the rounded part at a tangent and thus avoid any angle or projection.

The cylinder is hollow and open at one end. Fastened to the centre of the inside of the hollow cylinder is a metal stem (*b*), on to the free end of which screws a terminal. The total length of the electrode is 8 in.

(2) A cylindrical piece of vulcanite (*c*) the same diameter as the metal cylinder. The vulcanite is bored in its long axis by a hole down which the metal stem may pass easily. One end of the vulcanite cylinder is recessed to fit into the hollow metal end of the electrode.

To assemble the electrode the stem attached to the metal end is passed through the hole in the vulcanite tube. There is a small notch (*d*) at the base of the metal cylinder on its inner surface into which fits a corresponding stud (*e*) on the recessed part of the vulcanite cylinder. This is to prevent the parts from rotating on one another. The binding screw (*f*) is now applied to the stem and screwed up until the shoulder of the recess on the vulcanite is brought tightly home to the base of the metal cylinder. The binding screw should be loosened when the instrument is boiled.

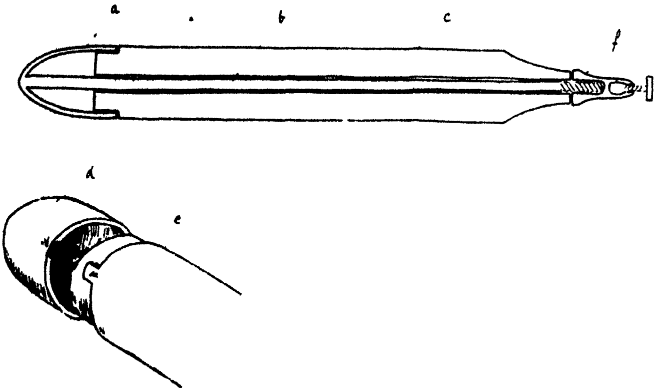

FIG. 85.—Vaginal Electrode. (The upper illustration shows the electrode in longitudinal section. In the lower illustration the metal and vulcanite cylinders are partly separated.)

**Technique.** The patient lies on her back with the pelvis slightly raised. The belt electrode is placed round the pelvis as for the intra-cervical treatments. The vaginal electrode is inserted as far as possible without causing discomfort. The current is switched on and increased up to 2 amperes. On account of the relatively large size of the metallic contact with the upper vaginal walls extreme accuracy of current-dosage is not necessary. Under ordinary conditions a current of 2 amperes gives a temperature in the immediate neighbourhood of the electrode of about 106° F.

There is sometimes a slight reaction during the day following the treatment, shown by some increase of pain or feeling of lassitude. This soon subsides, but it is always well to leave this day free from disturbance and not to repeat the application until the third day after the treatment. Applications are therefore made twice a week.

### IV. BACKACHE-CERVICITIS SYNDROME

Early in 1919 I began to apply direct current and diathermy to the cervix to remove infection. When this was accomplished the improvement in general health was very noticeable. Many of these patients told me that a backache from which they had suffered for long periods had completely disappeared. In many the symptoms of toxæmia were completely removed before the appearance of the cervix had returned to normal. The frequency of the association of cervical infection with ill-health and backache was so striking that I was led to examine cases complaining of backache for cervicitis and found it in a great number of them. The causal connection between the cervical infection and the symptoms was shown by the invariability with which removal of the infection resulted in relief, in most cases complete and permanent.

A clinical account of these cases will be given in some detail for several reasons. First, they are very common and the condition causes much disability among women. Second, they are often mis-diagnosed and consequently mistreated. It is common, for instance, to encounter women who have had their backs manipulated without benefit. It is therefore important to be able to recognise such cases. Further, they respond well to the treatment of the cervix.

The onset of ill-health occurs shortly after confinement or miscarriage, or there is a history of leucorrhœa. After confinement the puerperium may have appeared normal, but on getting up the patient failed to gain strength as she should. She remained languid and was easily tired and suffered from backache from the first. Often the lochia were blood-stained and excessive, lasting for some time longer than usual. During the puerperium there may have been some rise of temperature, which subsided to 99° F. or just over and continued so for some weeks. The toxæmia is often shown by a slight rise in the pulse rate.

When the leucorrhœa in this syndrome is not due to puerperal infection it is nearly always gonorrhœal in origin. The gonococci may not be found in smears—indeed, they may no longer be present, but the discharge may be due to a cervical infection with secondary invaders, to which gonorrhœa renders the tissues unduly prone.

The condition of ill-health and backache may be present for years until the complete backache-cervicitis syndrome is produced. The following is a typical clinical picture of this condition.

The patient appears ill. She is usually thin and looks tired with dark rings round the eyes and a sallow complexion.

Dyspepsia and flatulence, occurring for short periods or persistent, are common complaints and appear to be a more marked feature of the symptomatology than the general ill-health will account for.

Fatigue comes on early and renders the woman unfit to carry on her everyday occupation. The daily routine of a housewife in this condition is only performed with difficulty.

Bruises, either spontaneous or produced by slight trauma, are a common symptom. Sometimes there is a pricking sensation under the skin calling the patient's attention to one of these small extravasations. These are sometimes of considerable size ; I have come across several cases showing a small petechial rash on the lower parts of the leg similar to peliosis rheumatica. Occasionally the subcutaneous hæmorrhages are numerous enough to warrant a description of purpura hæmorrhagica.

The circulatory system is sometimes affected. The patient is chilly, easily influenced by cold wet weather and has cold hands and feet, which are bluish with slow capillary circulation. There is sometimes a soft general enlargement of the thyroid and I have come across one or two cases showing slight splenomegaly.

The mentality and temper are affected. The patient is worried about trifles, irritable and easily startled. To this is often added the effect on these women of realising that they are misunderstood and of being told that there is no physical basis for their pain. They are frequently told that they are suffering from "nerves," that they are "neurasthenic," "neurotic," or even "hysterical." They become insistent upon the severity of the pain in an attempt to convince those about them of its reality and their language in describing it becomes excessive. In severe prolonged cases they become almost demented.

The pain in the back is in quite the lower part in the neighbourhood of the sacro-iliac joints. It tends to radiate round the hips into the groins, to the lower abdomen and down the backs of the legs. Often it is down one leg more than the other, leading to a diagnosis of sciatica or of arthritis of the hip. Movement of the hips through full range and also of the vertebral column causes no increase of pain in most cases, though continued immobilisation on account of the pain may have produced a condition in which pain in the back is reproduced or increased by movement. Moreover, actual spondylitis may have supervened, as will be described later. The pain in the back is a referred pain from inflamed intra-pelvic structures.

The evidence of cervicitis may not be very marked. Considerable toxæmia can occur with a cervical infection producing nothing more apparent than some excoriation about the cervical os with a red granular appearance due to epithelial denudation. Exuberance of inflammatory manifestation in any focus is not an accurate measure of the severity of the resulting toxæmia.

The absence of leucorrhœa is misleading. Even hospital patients in whom no discharge visible at the outlet can be found may have well-marked cervicitis. There is some flattening of the fornices and the uterus is tender. The cervix is not as freely movable as it ought to be and manipulation of it causes or aggravates the pain in the back.

It is not very uncommon to find a soft inflammatory swelling at the vaginal outlet. This is tender when pressed upon. It may be that the swelling is present only in the posterior wall of the vagina producing a tender pad in the recto-vaginal septum near the outlet. There may be a similar thickening on the anterior aspect. Occasionally there is a complete ring round the vaginal orifice. This is due to extension of inflammatory œdema from the cervix along the cuff-like prolongation of the parametrial tissues around the vagina. It gives rise to frequent and painful micturition and pain on defæcation. It is a common cause of dyspareunia.

The urethral orifice is often marked by a ring of purple discoloration. The trigone of the bladder may be sufficiently involved to warrant the name interstitial cystitis. In such cases the urine is clear and a catheter specimen is usually sterile. Actual ulceration of the mucous membrane of the bladder, however, may occur and require special treatment. Occasionally the trigone can be seen on cystoscopic examination to be covered with a white membrane containing "sago-grain" thickenings in it ("pseudo-membranous trigonitis").

Menstruation is usually painful and the loss tends to be excessive. The inter-menstrual periods are often shortened and the duration of the periods prolonged. Usually during the periods, in addition to inflammatory dysmenorrhœa, the backache is increased.

In puerperal cases mastitis, which may become purulent, requiring incision and drainage, is often associated with cervicitis. Cases of recurrent abscess of the breast lasting for years have rapidly recovered upon the discovery and treatment by diathermy of a cervical infection. This has been a common experience at the West Middlesex County Hospital.

Infection of the cervix leads to lymphangitis and inflammation of the lymph-nodes draining the cervix. These are the parametric glands, the glands of the promontory and the lumbar and aortic glands, and when inflamed they give rise to tenderness in the middle line just below the umbilicus and along a line between the umbilicus and the anterior superior iliac spine on each side, *i.e.*, fairly high up in the abdomen, often associated with a curious absence of tenderness in the iliac fossæ. These areas are those often described as being due to visceroptosis, which is frequently confused with cervicitis. The lymphangitis causes the uterus to be bulky and tender.

## V. GONORRHŒAL CERVICITIS AND URETHRITIS

Early in 1919 I began to treat the cervix by diathermy as an investigation into the treatment of gonorrhœal arthritis. It appeared that the arthritis was, except in some severe and acute cases, not a pyæmia due to circulating organisms but a reaction of the joint structures, especially the synovial membrane, to a circulating toxin. It seemed rational therefore to treat the focus of infection and to concentrate especially on the cervix and prostate.

In January, 1922, I made a preliminary communication to the Electrotherapeutic Section of the Royal Society of Medicine and in July read a paper at the annual meeting of the British Medical Association on the results of this method. At that time I had treated 18 cases, all of whom at the time of commencing treatment had gonococcal infection of the cervix, some with urethra also infected, the infection being shown by positive smears.

Of these 18 all were finally declared free except 1. This case had four bi-weekly treatments, the first being on November 17th, 1919. On December 15th no gonococci could be found, also on January 6th, 1920, but on May 15th gonococci were again found. She did not attend any more, so that the final result was a positive bacteriological finding. Her husband had had gonorrhœa three times before marriage and the probability is that she was reinfected.

Of the remaining 17 cases all were finally negative in both cervix and urethra. Twelve had three to five treatments, 1 had six and 1 had nine. Three of the 17 cases had many treatments; 1 of these had three treatments with recovery after getting a separation from her husband. One recovered after her husband was treated at the Special Treatment Centre and the third recovered after a few treatments when an adequate amount of current was given, though she failed to do so during six weeks with an inadequate dose.

Up to 1929 I had treated 44 cases in whom the gonococcus had been found in smears. Of these 44 at the cessation of treatment no gonococci were found in 33, gonococci were still present in 3 and the result was not known in 8.

Of those in whom gonococci were still found 1 had four, 1 six and 1 many treatments. In the case of the last the diplococci, though present in large numbers, were all extracellular, and no leucocytes were seen. An acute arthritis of the wrist was completely cured.

Of the 33 patients who had no gonococci in the smears at the end of the treatment 15 were followed up for three months or more without relapse. Of these 7 were followed up for periods varying from six to fifteen months, the smears remaining negative during this time.

This work is open to the criticism that an adequate follow-up of the cases was not done. The attempt to do so was of course made, but the difficulties were insurmountable. From the point of view of whether the treatment is successful a systematic examination over a certain length of time is necessary. The treatment confers no immunity and if infection has once occurred it is extremely likely to do so again. Re-examination of such patients over long periods can often result only in finding the effects of re-infection.

### VI. INFLAMMATION OF THE PELVIC ORGANS AND CELLULAR TISSUES

A common example of pelvic inflammation has already been dealt with in the backache-cervicitis syndrome. In many cases, however, the lymphangitis and inflammatory infiltration may be sufficiently extensive to give rise to the clinical picture of parametritis, and in addition the tubes and ovaries may become inflamed. Chronic thickening of these structures may result from fibrosis. The uterus may be somewhat enlarged and tender and painful on movement for the same reason.

In these cases and in salpingo-oöphoritis the application of diathermy by the vaginal electrode as described produces softening, return of mobility and freedom from tenderness after two to three months' treatment.

In a certain number of cases treated there has been suppuration in the broad ligaments and other fibrous structures of the pelvis. In these the abscess has pointed in one or other fornix and has been opened and drained.

Fibrosis is not affected by the treatment, though in some cases the thickening of the pelvic ligaments and of the tubes ceases to cause symptoms after the treatment by pelvic heating and after the cervix has been rendered normal. In such cases the pain has probably been due to inflammation in the adhesions. The pain of fibrotic contraction is not relieved by it.

Inflammatory dysmenorrhœa is relieved with the rest of the symptoms and the menstrual flow becomes regular and normal in amount. Spasmodic dysmenorrhœa is not cured by it, but relief of pain is almost invariably obtained for the first period after a month's treatment. I have given diathermy for a whole year after this relief at the first period and watched the pain gradually recur until at the end of the year it was as bad as at first.

At the time of the menopause a metritis is liable to occur in association with cervical infection which may have been long-standing and may show comparatively slight local signs. Often there is nothing more to be seen than a dark red rim to the os. The uterus is somewhat enlarged and there is a referred pain in the back. In these cases the effects of the toxæmia added to the mental instability of the menopause are apt to produce a condition bordering on insanity. These cases usually respond well to heating the pelvis with the vaginal electrode.

In 1929 I published reports on the treatment of pelvic inflammation in 41 cases.

Seventeen of these were of salpingitis of undetermined origin. Twelve of them recovered, 1 had three treatments only and the result was inconclusive, 3 made a partial recovery and 1 recovered with relapse of cervicitis later. In this last instance the cervix had been treated by ionisation. Two patients became pregnant shortly after cessation of treatment.

Seven cases were due to gonococcal infection. Five were cases of salpingitis and 2 of peritonitis with gonococci found in peritoneal pus. All recovered after a short period of treatment, with smears negative to gonococci, 1 during six months' observation, 1 five months, 1 three months and the rest one month only.

A group of 12 cases had salpingitis and some of them parametritis as well following shortly after confinement. These cases as a rule made a good recovery. They all had physical signs of salpingo-oöphoritis. Two of them definitely failed to improve after six months' treatment. In 1 case the cervicitis relapsed, but not the salpingitis, and she ultimately recovered. Two became pregnant shortly after cessation of treatment.

Of 2 cases of parametritis with deep lacerations of the cervix, 1 recovered and the other had too short a course to benefit.

In 3 cases the pelvic inflammation had followed operation for ectopic gestation. Two of them recovered, the third had insufficient treatment.

Twenty-five of the total number had cervicitis. One of them received three treatments only. Twenty-two recovered of salpingitis, but 2 of them had relapse of cervicitis. Two recovered as far as physical examination was able to establish the fact, but subjective symptoms remained.

Since 1929 I have treated cases of the same sort with similar results.

## B. THE MENOPAUSE

Menopausal disturbances can be grouped into two categories :—

(1) Conditions which are directly due to the menopause, *i.e.*, menstrual disturbances, subjective vasomotor phenomena, myxœdema and menopausal arthritis ; (2) conditions which precede the menopause and which are aggravated by it, *e.g.*, backache-cervicitis syndrome and infective arthritis. This classification is etiological. It is of practical value in that it gives an indication for an effectual line of treatment.

### I. CONDITIONS DIRECTLY DUE TO THE MENOPAUSE

The menopause is a period of hormonic discord. The endocrine glands are undergoing involutionary changes at varying rates, so that the normal balance between their different secretions is disturbed. This results in many unpleasant symptoms and for the last fifteen years I have applied intrapelvic diathermy for their relief. The technique of the treatment is precisely the same as that already described, *i.e.*, the large vaginal electrode is used with a lead belt round the pelvis.

Although the use of diathermy for these conditions was, in the early stages of the work, almost wholly empirical, recent work on the functions of the female pelvic organs has helped towards an understanding of the scope and some of the limitations of the method. The mechanism of its action is not understood, but it is suggested that the ovaries are heated and thus the endocrine balance in some way restored.

**Menstrual Disturbances.** Menstruation often becomes irregular during the early stages of the menopause, the patient complaining of frequent small losses. Diathermy often succeeds in regulating the menstrual cycle, and since 1922 I have been treating such cases by this method with marked benefit, the cycle rapidly returning to the twenty-eight days.

**Vasomotor Disturbances.** The best known of these are "flushings," but a great variety of abnormal sensations may be complained of. In course of time they pass off, but they may last for many years and may be very severe. Intrapelvic diathermy has a marked effect, many patients declaring themselves relieved completely after one or two courses of treatment.

Two other endocrine conditions are frequent accompaniments of the menopause, namely, myxœdema and menopausal arthritis.

**Myxœdema.** At this time of life the activity of the thyroid begins to flag, so that a certain degree of hypothyroidism is practically normal. A detailed description of this would be out of place here, but the frequency with which it occurs in association with other menopausal manifestations has led me to give thyroid extract in small doses (gr. ¼ t.d.s.) to most of these patients.

One interesting peculiarity, not constant, but by no means rare, is that the "myxœdematous" pads found in various places (dorsum of the foot, inside the knees, over the cervical vertebræ and elsewhere) may be tender—so much so in some patients that one is reminded of adiposis dolorosa. Sometimes the pain and its distribution exactly resemble " fibrositis " of the shoulders, neck and arms, and such cases are often relieved by one or two courses of intra-pelvic diathermy.

**Menopausal Arthritis.** This will be dealt with in the next chapter.

### II. CONDITIONS ANTECEDENT TO, BUT AGGRAVATED BY, THE MENOPAUSE

**Backache-cervicitis Syndrome.** This has already been described. When this form of toxæmia is added to the mental and endocrine instability of the menopause the patient's condition becomes much worse. In these cases intra-pelvic diathermy followed by urethral and cervical treatment will effect marked relief of symptoms.

**Infective Arthritis.** In many cases the backache-cervicitis syndrome is complicated at the time of the menopause not only by increase in severity of the backache but by infective arthritis as well.

The effects of infective arthritis, due to the toxæmia of an infected cervix added to the proliferation and degeneration of bone and cartilage at this time, frequently produce great destruction of the joint and consequent loss of mobility and crippling. One or two or many of the joints may be affected, but it is perhaps seen most markedly in the hips. Within a year or two of the onset there may be almost complete fixation.

Cervicitis then becomes a problem of special importance at the menopause. As I first showed in 1919, intracervical diathermy is effectual in removing, not only the cervicitis, but also the metastatic lesions. This subject will be dealt with in more detail in the next chapter.

# CHAPTER XV

## MEDICAL DIATHERMY IN CHRONIC ARTHRITIS

BY

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DIATHERMY can be used in two ways in the treatment of arthritis :—

(1) *Local*, in alleviating pain and aiding the subsidence of swelling in the joints. For this purpose it ranks with direct current, infra-red irradiation and similar physiotherapeutic measures and it possesses no advantage over them, except in the case of gonorrhœal arthritis, where its beneficial effect is rapid and pronounced.

(2) *Focal*, in eradicating infection in the cervix and prostate, where either of these constitutes the focus responsible for the arthritis.

In the present chapter only chronic non-specific arthritis and gonorrhœal arthritis will be dealt with. Chronic arthritis is divided into two types :—

(1) *Infective, atrophic* or *rheumatoid arthritis*, which is an inflammatory manifestation in the joints due to their reaction to a focus of infection. It must be emphasised that the condition is a systemic one, the joint affection being but one item in the syndrome. It follows that treatment directly applied to the joints can never be more than palliative whilst the focus is active. This focus is, in the vast majority of cases, the cervix in women and the prostate in men. Effectual treatment applied to either of these foci will in such cases result in arrest of the arthritis, whether the joints themselves are treated or not. Since both cervicitis and prostatitis are forms of pelvic infection, it will be seen

that in so far as this chapter deals with rheumatoid arthritis it is a direct and logical continuation of the preceding one.

(2) *Degenerative, decrescent, hypertrophic* or *osteo-arthritis,* which is a non-inflammatory affection of the joints due to senescent changes. It is not associated with any form of bacterial toxæmia and no focus of infection is responsible for it. In some cases, at least, an endocrine imbalance probably plays a part in its etiology. When it is due to changes consequent on advancing age it must remain incurable, though it can be alleviated to some extent. One special form of it, namely, menopausal arthritis, can be arrested by means of diathermy, as will be described later.

In order to apply diathermy correctly in a given case it is obviously essential to be able to recognise from which type of arthritis the patient is suffering. The following outline is therefore given of the clinical and radiological characteristics of the two types :—

## I. INFECTIVE OR RHEUMATOID ARTHRITIS

### A. IN WOMEN

This condition is four or five times as common in women as in men. The onset occurs in the overwhelming majority of cases during the child-bearing period of life, that is, from eighteen to forty-five. Thus, most of the patients are comparatively young at the time of onset.

The commonest *history* is that of ill-health either coincident with or preceding the arthritis, dating back to childbirth or miscarriage, both of which may initiate cervicitis. Quite commonly the patient dates the onset to her marriage, and in some of these cases the origin of the cervical infection is not so evident, though there is no doubt that gonorrhœa plays a big part. It is possible that in some cases, especially in virgins, the acute specific fevers and also appendicitis are factors in bringing about infection of the cervix.

The *clinical findings* are as follows. The patient is usually thin, sallow and often anæmic. There may be occasional or persistent slight pyrexia. The joint affection is a polyarthritis, the brunt being borne by the smaller joints such as those of the fingers, wrists, toes and ankles, though the large joints do not escape. The arthritis is often symmetrical. The finger-ends are atrophic and cold and many of the patients exhibit a peculiar dampness or clamminess of the hands and fingers.

The affected joints are swollen, the fingers, for instance, exhibiting a fusiform enlargement which is typical. It may be said, in general, that fusiform enlargement is characteristic of infective arthritis while nodular enlargement is characteristic of osteo-arthritis. The joints are stiff and movement is painful and limited. There may be destruction of the joints leading sometimes to complete fixation, seen commonly in the wrists and ankles, and sometimes to subluxation and splaying of the articular ends due to the pull of the tendons and consequent hypermobility, seen most often in the metacarpal-phalangeal joints. Great deformity is thus produced and ulnar deviation of the fingers is a typical finding. Bony ankylosis is quite common.

There is commonly abdominal tenderness of exactly the same type and distribution as was described when dealing with cervicitis in the last chapter. The condition of the cervix varies somewhat with the stage of the arthritis. It is common to find signs of active infection with excoriation and discharge associated with tenderness in the fornices; but in long-standing cases the cervix may exhibit only the signs of past infection, that is to say, it may be deformed and bear white scars radiating from the os, where the excoriation has healed; and there are often Nabothian follicles dotted about in its substance. In such cases the focus has died out and the arthritic process has become arrested.

*X-rays* show the following changes. In many cases, even of severe arthritis, the only alteration to be seen in the bone is rarefaction of the bone ends, though there may be in addition some diminution in joint space. Thickening of the periarticular soft tissues is usually evident in a skiagram of the fingers. In other cases the bone adjacent to the joint surfaces is seen to be irregular and ulcerated and the bone ends contain irregularly arranged areas of rarefaction and sclerosis, the normal lamellar bone structure being destroyed. In many such cases bridges of bone will eventually form across the joint space and cause firm ankylosis.

In many cases of infective arthritis, particularly those in which a few large joints such as the hips and knees and also the vertebral column are most affected, the main radiological feature is the formation of inflammatory new bone in the tendons attached round the joint, in the capsule and in other periarticular structures. In the X-ray plate this shows as an outgrowth from the bone near the joint, somewhat resembling the " osteophyte " of osteo-arthritis and commonly reported as such by radiologists. It is important to make a distinction between them, since in such cases the method of treatment to be adopted may depend to some extent on the correct interpretation. Inflammatory new bone is seen in the X-ray as a spur, which is as dense as, or denser than, the normal bone, is structureless and shades off rather like a tuft of cotton wool into the surrounding structures, so that its outline is not clearly marked. The true osteophytic outgrowth characteristic of osteo-arthritis, on the other hand, is not denser than the normal bone, it often shows the lamellated structure of true bone, and instead of shading off gradually into the surrounding structures it has a thin, but (in a good X-ray) clearly marked external outline or shell of dense bone. It thus resembles a bubble rather than a tuft. The structure of these osteophytes may be studied best in a good lateral X-ray of a finger showing Heberden's nodes.

**Natural History of Chronic Arthritis.** (*a*) *Modes of Onset.* There are five distinct modes of onset in women :—

(1) In the first type the joints are found to be affected in two ways. Some are fixed and the X-ray shows more or less destruction in them, while others show atrophy of the bones with dislocation, splaying of the articular ends and periarticular infiltration. The history shows that the fixed joints were affected early, and that fixation occurred rapidly. Subsequently the other joints became involved slowly and insidiously. I am convinced that these fixed joints are affected by a pyæmic process caused, for

instance, by gonorrhœa or puerperal sepsis. The acute process in the focus eventually dies out, leaving behind a chronic cervicitis, and the resulting toxæmia slowly affects the other joints.

(2) In some cases the joints are involved insidiously, pain and swelling leading in the course of years to complete crippledom. In this form ankylosis does not occur.

(3) The " rheumatic fever " type of onset. The condition resembles acute rheumatic fever almost exactly, with malaise, sweating, pyrexia and fugitive joint pains, but there is no response to salicylates and no cardiac lesion, the heart showing no abnormality on the electrocardiogram. A further point of differentiation is the fact that a first attack of acute rheumatic fever is rare in adult life. The joint condition is fugitive to begin with, but the inflammation tends to settle in one or more joints which then show signs typical of arthritis.

(4) In this type the actual onset of the arthritis is preceded by months or even years of backache and vaginal discharge dating from a confinement or miscarriage. This antecedent condition has been described in detail in the last chapter under the heading of the backache-cervicitis syndrome. It often passes almost imperceptibly into typical rheumatoid arthritis, the joints being involved slowly one after the other. The backache and discharge persist, but they are pushed somewhat into the background by the later additions to the picture.

Allusion has already been made in Chapter XIV. to the transition of this backache syndrome into chronic arthritis, and emphasis must again be laid here on the importance of being able to recognise it. This type of onset and the next to be described are the only ones in which a definite and long-sounding note of warning is given of the approach of arthritis. The backache-cervicitis syndrome is to be regarded as a *pre-arthritic* condition and for some years now

I have treated it with diathermy with the conscious object of exercising prophylaxis against rheumatoid arthritis.

I believe that this is a most important concept. A moment of digression from the main subject of this book may perhaps be allowed in order to consider briefly how much further prophylaxis could in fact be carried. For chronic arthritis is commonly due to puerperal infection ; and there can be no doubt that an effective means of preventing puerperal sepsis would mean a considerable fall in the incidence of chronic arthritis. In fact, the prevention of this form of arthritis in women lies largely in the hands of the obstetricians.

(5) A definite type occurs in which the onset is in association with the menopause. This is often confused with osteo-arthritis owing to the greater age of the patient, and indeed both forms of arthritis may co-exist in the same patient and even in the same joint, though they can usually be separated with practice. The history reveals the fact that the patient has suffered from backache and vaginal discharge, most commonly dating from the birth of the youngest child. The toxæmia has thus existed for some time and the disturbed conditions at the menopause, for some reason unknown at present, determine the onset of the metastatic joint lesions.

(*b*) *Progress.* The natural progress of infective arthritis in untreated cases is very capricious. Some patients go steadily down hill, either rapidly or slowly ; others have frequent remissions and exacerbations. In the long run the course of the disease is progressive and the majority of cases become crippled, either partially or completely. At the same time it must be remembered that approximately 25 per cent. of all cases undergo spontaneous recovery. From these facts it will be seen that great care must be taken in making claims for any particular kind of treatment and that the cases must be watched over long periods of time.

**Treatment.** (1) *Focal.* This is exactly the same as for pelvic infection and is described in detail in Chapter XIV.

The first result is an improvement in the patient's general health. Often the pain in an acute joint subsides rapidly and almost always an improvement is noted in the joints before the focal treatment is concluded. Frequently, however, there is a marked reaction to the treatment, the joints becoming more swollen and painful for the time being.

(2) *Local.* After the focus has been eradicated the joints themselves are treated. The keynote here is mobilisation. The soft tissues are prepared by direct current applied to the joints either by means of pads soaked in saline or arm- or leg-baths or diathermy and other measures. Passive movements are begun, gently at first, and the patient is encouraged to use her limbs for ordinary occupations, such as knitting, sewing, walking, etc.

Further details concerning local treatment are beyond the scope of this chapter, but it must be emphasised that these measures must nearly always be applied for long periods of time. In cases of great severity the total length of time during which patients are under care is about three years, of which three months are occupied in treating the focus. During this time the patients make steady progress and finish by presenting as cures, except that any joints which have been sufficiently disorganised or destroyed by the disease remain fixed. The amount of recovery which takes place varies directly with the damage done, but in several cases I have observed re-growth of cartilage as shown by restitution of the normal joint space in an X-ray and complete restoration of function in joints which had appeared to be destroyed.

### B. IN MEN

As indicated, infective arthritis is not so common in men as in women. The onset occurs at any age from puberty onwards with a rather greater predilection for the later decades of life. The differences in the age-incidence in the two sexes can be explained by the following facts :—

(1) Both the cervix and prostate are about equally exposed to gonorrhœa, and other similar infective factors. Cases are therefore rare before puberty, but occur throughout adolescent and adult life.

(2) But the cervix runs the additional risk of child-birth and miscarriage, though it becomes atrophied some years after the menopause. Hence the majority of cases in women occur during the child-bearing period, and this type of arthritis coming on after the age of sixty-five or so is rare.

(3) On the other hand, the prostate often becomes enlarged, degenerate and more prone to infection after middle age. This explains the slight increase in the incidence of arthritis towards the end of life in men.

The *history* does not usually date to an event or epoch in life, as in women. In cases occurring late in life a coincident history of nocturnal frequency of micturition is not at all uncommon. Sometimes the onset of the arthritis is preceded by a period of ill-health, in which backache and lassitude are prominent features.

The *clinical and X-ray appearances* of the joints differ in no essential features from those in women.

Examination of the abdomen commonly reveals some tenderness in the lower part, often on one side only ; and this tender area will almost always be found hyperæsthetic to pin-prick, the sensitive area encircling the body like a half belt and corresponding to the lower thoracic and upper lumbar segments of the cord.

Examination of the prostate may reveal nothing abnormal, but if the prostate is tender on one side there will nearly certainly be found a tender and hyperæsthetic area on the abdominal wall on the same side. There may be general prostatic tenderness and the gland may feel boggy or hard in one lobe or generally nodular. Thus the physical signs are variable and not of much assistance ; similarly, microscopic examination of prostatic secretion expressed by massage is often not particularly helpful, though of course gonococci may be found in some cases and in others an indication of the presence of a chronic non-specific infection may be given by excess of leucocytes. But chronic prostatitis may be present without symptoms or signs and we have to fall back on the therapeutic test ; treatment of the prostatitis by diathermy will result in arrest of the arthritis, if the two are etiologically connected.

**Natural History.** (*a*) *Modes of Onset.* In men there are four main modes of onset. They are the same as the first four described when dealing with arthritis in women, namely :—

(1) Rapid involvement and fixation of a few joints, followed by slow development of non-ankylosing arthritis in others.

(2) Slow insidious onset in all the joints affected.

(3) The "rheumatic fever" type of onset.

(4) The backache-prostatitis syndrome, *i.e.*, the counterpart of the backache-cervicitis syndrome in women. These cases are quite common and most of them start originally from an attack of gonorrhœa, often many years before. This may have been successfully treated and there may no longer be any discharge or other symptom of local infection. But the patient suffers from easy fatigue and listlessness and has a low backache, sometimes with abdominal pain. The indigestion and other disturbances described in the case of women are found also in these men. Apart from the pain in the back, however, the outstanding symptom is "nervousness," which is often so marked that these cases are labelled "neurasthenia." This mis-diagnosis is so common that I have made it a rule to examine such cases carefully for prostatitis, and have found it and treated it successfully in a high percentage.

This syndrome is a pre-arthritic one, both rheumatoid arthritis and spondylitis ankylopoietica being common sequelæ.

(*b*) *Progress.* An untreated case follows the same course in men as in women, remissions and exacerbations being common, while the general trend is progressive. In both sexes the disease tends to be complicated in its later stages by the development of osteo-arthritis affecting the same or other joints.

**Treatment.** *History of the Method.* While working at St. Bartholomew's Hospital in the years immediately following the European War I devised the methods described in previous pages for the treatment of gonococcal cervicitis and urethritis by diathermy and found that an associated arthritis rapidly subsided when these foci were so treated. It seemed logical to examine women suffering from non-gonococcal arthritis for infection of the cervix and I discovered it to be almost an invariable finding. Successful treatment of such cases and prolonged observation of them led me to the conception of chronic infective arthritis outlined in the last section.

At the same time it also seemed feasible to attempt the treatment of the prostate by similar means. I had already made the observation, parallel to that in the female cases, that heating the infected prostate in gonorrhœa rapidly relieved an associated arthritis, with consequent subsidence of pain and swelling. Encouraged by success with female cases of rhematoid arthritis I tried the effect of diathermy applications to the prostate in male cases and was rewarded by success in a large proportion of them.

**Description of the Instruments and Method used in treating Prostatic Infection.** The problems involved in attempting to apply diathermy to the prostate are more difficult of solution than in the case of the cervix. The prostatic urethra is sensitive and much more difficult of approach, so that it has been found better to heat the gland from behind by means of an electrode placed in the rectum.

The same indifferent belt electrode is used as in women. A description of the rectal electrode will be found in Chapter XIII, pp. 191, 192.

*Technique.* The patient lies on his back and the lead belt is placed round the pelvis and connected to one cable of the machine. The rectal electrode is then smeared with vaseline and pushed gently into the rectum until the vulcanite button comes up against the anal margin. A small towel wrapped round it between the patient's thighs is quite sufficient to prevent it from slipping out. The other cable from the diathermy machine is now attached to the terminal of the electrode and the current switched on. It is increased until the patient experiences smart heat in the pelvis, but he must not be allowed to feel pain. An average and safe dose is 1 ampere and there is no advantage in exceeding it. Each treatment lasts twenty minutes and treatments are usually given twice weekly. It has been found by experience that if good results are to be obtained a course lasting at least three months must be given.

This constitutes the focal treatment of infective arthritis in men ; and, just as in women, improvement in the general health of the patient and of the condition of the joints often begins before a course of treatment has concluded.

Local treatment in the joints is then begun and what has been said already in the case of women applies here also. Mobilisation is the essence of the method and prolonged treatment must be expected.

## II. DECRESCENT OR OSTEO-ARTHRITIS

Diathermy has no place in removing the etiological agent responsible for this form of arthritis as ordinarily met with. But one special variety of it is amenable to intrapelvic heating, namely, menopausal arthritis. This condition is part of the menopausal syndrome. It has a variable time relation to the cessation of menstruation ; it may come on several years before or round about the time of the cessation or several years afterwards. It is therefore commonly associated with menstrual irregularities, subjective symptoms and especially hypothyroidism. It may affect any joint, usually the larger ones, though the small joints are not exempt. Those suffering most are the weight-bearing joints, such as the knees, and those specially bearing the brunt of hard work, such as the first carpo-metacarpal joints of manual labourers.

The joint appears enlarged, the appearance being chiefly due to the myxœdematous pads previously mentioned, and thickening of the periarticular structures. The actual joint cavity is distended in most cases with enlarged synovia or with synovial fluid due to trauma from pinching of the intra-articular structures. Normal use amounts to trauma in joints in this condition. The line of the joint is tender and the movements are restricted. There is no local heat, unless synovitis is superadded. Patients often complain that the knee " locks " and then spontaneously recovers and that the joint " gives way " and " lets them down."

*Some ridging of the articular margin can be felt at an early stage, and rubbing the patella on the underlying cartilage gives a sensation of roughness instead of the normal feeling of perfect smootheness. X-rays reveal proliferation of bone ("lipping") at the articular margins.*

It was about 1922 that while treating the menstrual irregularities of the menopause by diathermy I first noticed that many of the patients also suffered from this form of joint affection, and further that this was relieved along with the other symptoms. A radiological study of the condition revealed a pathological picture identical with that of osteo-arthritis; and the general family resemblance between these two conditions and acromegaly, myxœdema and fibrocystic disease of bone led me to postulate that they had their origin in some endocrine disturbance. Llewellyn expressed the opinion that menopausal arthritis did not differ in essentials from osteo-arthritis and stated: "I believe that future research will show that all varieties of osteo-arthritis hark back to similar etiological factors, endocrine disturbances playing a fundamental rôle." In 1926 I published an account of several cases of this type of arthritis occurring in young women suffering from amenorrhœa of endocrine origin; the joint affection began to improve as soon as normal menstruation had been restored by intrapelvic diathermy.

The beginning and the end of adult life are marked by re-arrangements in the balance of power between the ductless glands. The total effect of these re-arrangements towards the end of life makes up one aspect of what we call senility: and decrescent arthritis is a common manifestation of it. In old age there is about the same liability to decrescent arthritis in the two sexes. But in women there is often a kind of phase of senility at the menopause: in them there is a definite event, which determines the onset of bone and cartilage changes of the same type as those of old age. This phase usually passes away completely and may be replaced after an interval by ordinary slow-coming senility, as in men. The joint affection thus ranges itself with the evanescent symptoms of the menopause, which in passing away leaves the arthritis in an arrested condition.

The amount of damage done to the joints thus depends on the length of time the menopause has lasted: new bone once laid down will always remain. Shortening the time correspondingly lessens the amount of damage. Intrapelvic diathermy by the vaginal electrode combined with thyroid extract arrests the progress of the arthritis in a comparatively short time—in months instead of years—and thus bestows on the patient a more active post-menopausal life. The decrescent arthritis which comes on later must remain incurable until a cure is found for old age.

In the later stages of an untreated case, when much proliferation of bone has already taken place and the patient finds difficulty in getting about owing to limitation of movement by bone-hypertrophy, synovial changes or periarticular thickening, the condition can be mitigated by the use of direct current applied to the joints, followed by passive movements. Mobilisation is an essential part of the treatment.

### SPONDYLITIS

This disease is placed under a separate heading in deference to common usage, but in essentials it is the same as chronic arthritis. There are two types :—

(1) *Infective spondylitis* or *spondylitis ankylopoietica,* due most commonly to cervical or prostatic infection, either gonococcal or otherwise. When this is not the case its origin will be found in intestinal or gastric ulceration, following dysentery or otherwise. Intestinal toxæmia is not a cause of infective spondylitis or arthritis unless the lymphatics or intercellular spaces are opened up by ulceration.

(2) *Degenerative* or *decrescent spondylitis* or *spondylitis deformans,* in which the changes are those of osteo-arthritis occurring in the vertebral column.

The first type is characterised by inflammatory changes in the ligaments of the vertebral column, especially the anterior common ligaments. Inflammatory new bone or, more accurately, calcification occurs in these structures and becomes visible in the X-ray. The condition results in pain and great limitation of movement in the spine, the end-result being the well-known "poker-back" spine. It is nearly always associated with inflammatory changes in the sacro-iliac joints, which are often affected before the spine. This condition is due even more commonly than chronic infective arthritis to prostatic infection, but if curative results are to be obtained cases must be treated early. Even when there are changes visible in the X-ray, however, some return of mobility and subsidence of pain occurs after a course of rectal diathermy followed by measures aimed at mobilisation of the spine.

Osteo-arthritis of the spine is an incurable condition which, however, can be alleviated to some extent by local measures and passive and active movements.

# CHAPTER XVI

# FIBROSITIS, COCCYDYNIA, METATARSALGIA

## Fibrositis

DIATHERMY is of value both in acute and in chronic cases of fibrositis. In acute cases, however, it is seldom possible for the patient to receive it because absolute rest is essential and diathermy is not often available at home. In chronic cases, diathermy is one of the most valuable therapeutic agents. It should be given in combination with massage or movements.

The active electrode should be a well-padded disc, 1 to 2 in. in diameter. It is held by the operator and slowly moved over and around the tender parts, kneading movements being performed at the same time. The combined treatment can be conducted on a condenser couch. Methods are described on p. 164. The method in which the operator sits on the couch is particularly useful because he can use his fingers in place of an electrode for administering the diathermy as well as the massage.

The séances should be held not less frequently than thrice weekly. They may, with advantage, be held once a day.

After each application of diathermy it is a good plan to perform a few passive movements, the object being to increase the range of movement which the fibrositis has limited. Without causing undue pain the operator will generally be able to move the part through a greater range just after each application of diathermy than was possible before. The addition to the range lasts for longer periods while the course of treatment is in progress and eventually the full extent of movement without pain is usually obtained.

Cases of long-standing fibrositis are encountered in which there is no complaint of pain at rest or within a restricted range of movement. But on attempting to perform full movement the pain is elicited. Thus when it occurs in the vicinity of a joint like the shoulder, which normally allows movement in all directions, the pain may be felt on movement in one direction only. If the treatment above described is not successful in obtaining full range of painless movement the diathermy may be followed by the application of vibratory massage to the muscles which bring about the pain when they contract. Alternatively, the muscles may be made to perform a succession of twitches of gradually increasing amplitude. The twitches can be produced by means of an induction coil fitted with a slowly moving interrupter. The so-called Morton-wave current from a static electrical machine is very efficient for the purpose in cases where the muscles concerned are deeply situated. Whichever current is utilised there should be a preliminary application of diathermy.

In the type of case mentioned above it is possible that scar tissue has replaced the fibrositis and created adhesions. The method of action of the electric currents, other than the diathermic, is mechanical. The twitches or tugs of the muscle loosen or rupture the adhesions.

## Coccydynia

Patients who complain of pain and tenderness in the region of the coccyx and exhibit no signs of disease of the spine or pelvic organs usually derive relief from diathermy. It should be applied by way of two electrodes, one of which is placed in the rectum and the other over the coccyx and lower part of the sacrum. The current should be strong enough to produce gentle warmth. The treatment should last for twenty minutes and be repeated twice or thrice weekly.

Most of the writer's cases have been in women. One occurred in a man who was under treatment for paralysis of certain muscles of one hand and the opposite forearm. He complained of "pain in his tail" when he sat on a hard seat. On examination the coccyx was found to be tender on pressure. A course of diathermic treatment abolished the pain and there was no recurrence of the trouble. Later on he developed proctitis but the coccydynia did not return.

## Metatarsalgia (Morton's Disease)

The author has obtained some successful results in the treatment of obstinate metatarsalgia by diathermy. The first 2 cases described below had resisted other forms of treatment and were sent to the electrical department.

*Case* 1. Male, aged 43. This patient had suffered for eight years from pain in the fore-part of each foot. Surgical operation had been performed on four occasions without lasting benefit. Diathermy was applied twice weekly for a period of three months. Each foot was treated separately for seven minutes at each session. One electrode was placed on the ball of the foot, the other on the calf. As the treatment proceeded the pain lessened and at the end of the course he was able to walk considerable distances without pain. These results lasted for three years. Pain then recommenced. After a second course of diathermy lasting three months the pain was less and felt only after walking.

*Case* 2. Male, aged 50. The patient had suffered from acute pain in the fore-part of the right foot and in the left heel. The heads of the metatarsal bones were tender on pressure. Diathermy was applied by way of electrodes placed respectively under the left heel and under the ball of the right foot. The first application procured complete relief for twelve hours. Treatment was continued twice weekly for five weeks. At the end of the course the pain was so slight that the patient was able to resume work.

The third case was one of severe pain in the heads of the metatarsal bones. The metatarso-phalangeal joints were said to present the radiographic appearance of osteo-arthritis. By reason of the results obtained by diathermy and their permanence it seems unlikely that pain was due to osteo-arthritis.

*Case* 3. Male, aged 32. The pain developed while travelling in the tropics and was still present when he came to England six months later. There was a history of gonorrhœa. The patient said that he had been cured before the pain in his feet developed. When examined by Mr. Kenneth Walker on his arrival in England there was no evidence of gonococcal infection.

Diathermy was applied to the feet. After sixteen applications the patient was able to take strenuous exercise without pain. Three months later he wrote to say that he was able to walk ten to fifteen miles daily without pain. Some years later his doctor told the author that a permanent cure had apparently been effected.

# CHAPTER XVII

## DISEASES OF THE CARDIOVASCULAR SYSTEM

BY

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Diathermy is one of the most powerful agents we have for influencing the general and local circulation ; it helps to relax any arterial spasm which may be present and it also decreases the viscosity of the blood. In this way the peripheral resistance of the circulation is diminished and so the work of the heart is greatly lessened, while the tissues themselves become hyperæmic. This effect explains the beneficial results of diathermy in lowering the blood pressure in patients with hypertension, while its effect in improving the coronary circulation undoubtedly explains the improvement which takes place in angina pectoris when diathermy is applied locally to the heart. The general heating of the tissues produces an analgesic effect which is an added factor in its relief of the pain in angina pectoris.

The adoption of diathermy in the treatment of circulatory disorders dates from Nagelschmidt's classical paper published in 1912 in the *Archives of the Roentgen Ray* (now *The British Journal of Radiology*) (1).

In this paper he recorded the remarkable results obtained in the treatment of cases of intermittent claudication and high blood pressure by diathermy, and found that it was in what we would now term the " Essential Type of Hyperpiesia " that the best results were obtained. He also described his experiences in the treatment of severe cases of angina pectoris, all of which derived considerable benefit, some of them to a remarkable degree ; while he was the first to note the curious feeling of well-being which was often experienced under this treatment, instancing the statement of one patient aged fifty-two, who said that she felt like she did ten years earlier. This sensation of well-being is very commonly met with, and we have noted it again in our cases when under treatment. It is of interest to note that Nagelschmidt also advocated the treatment of diabetic gangrene by means of diathermy.

The effects of high-frequency currents in reducing high blood pressure have also been described by Sir T. Clifford Albutt (2) who believed that it was not a temporary effect only which was experienced, but a permanent lowering of the pressure.

In 1926 Hay and Ince (3) recorded their experiences in the treatment by diathermy of 8 cases of angina, 5 cases of hypertension and 1 case of intermittent claudication.

They showed that in hypertension there was as a rule a small but appreciable fall in the average systolic pressure, but not much material change in the diastolic pressure. Though this was the only objective change noted in these cases, there was a marked subjective effect on the patients. There was an increased feeling of well-being ; they became much more active and many of them expressed the opinion that they felt many years younger—a phenomenon already noted by Nagelschmidt. In the cases of angina pectoris they also observed that the cardiac reserve power was so increased that patients who before treatment were unable to walk 50 or 100 yards without having to stop because of the pain, could afterwards walk many times this distance without distress, and in some cases the pain completely disappeared.

Since this period Dr. Hay and I have treated in the heart department of the Royal Infirmary and in private practice over 76 cases of cardiovascular disease with diathermy—36 of these fall into the high-tension group, while 40 are examples of angina pectoris.

### The Effect of Diathermy on High Blood Pressure

In the first place it is necessary to explain the technique of the treatment used. Most of the cases were treated by means of a Watson's Spark-gap Machine using a current with a periodicity of about 1,000,000 cycles per second, the electrodes being applied to both hands as a rule, but occasionally to both feet as well. The electrodes were of the flexible metal type and were wrapped round the wrists ; a current of ¼–½ ampere was used at first, and only ten to fifteen minutes' treatment given. After two or three treatments the current was increased to 1 ampere and the length of treatment to half an hour.

The patients during the treatment experienced a slight degree of heat accompanied by moderate perspiration, followed in the successful cases by a feeling of well-being lasting some hours. Occasionally the treatment was followed by a temporary feeling of exhaustion, and in these cases the good effects were as a rule not so marked as those in which there was a feeling of well-being. Some patients experienced during the actual treatment severe throbbing in the head and dizziness which was so distressing that it had to be stopped. In the majority there was a moderate

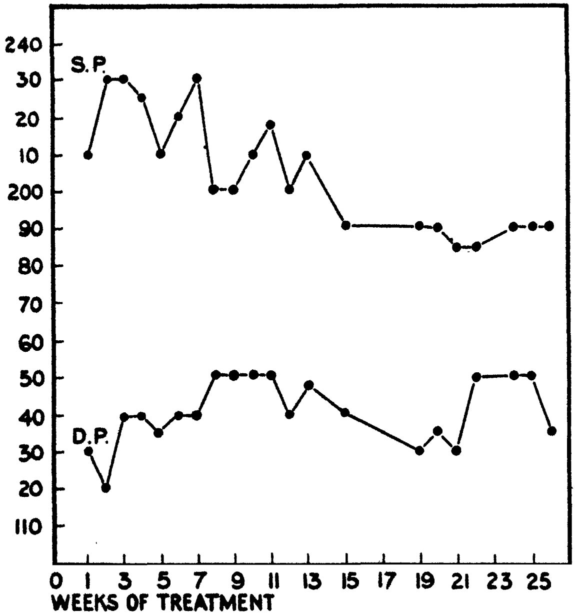

FIG. 86.—CHART I.

persistent fall in the blood pressure accompanied by the subjective sensation already mentioned.

*Case* 1. A male, aged 49. High blood pressure with moderate albuminuria: 210/130 mm. Hg. Electrocardiograph: Left ventricular preponderance; negative T. (leads I. and II.). Clinically: Shortness of breath on exertion with loss of vision in the right eye (due to optic atrophy) and severe headaches.

He was given diathermy from wrist to wrist three times a week for a period of about five months, the current used being about 1 ampere. This resulted in a fall in the systolic pressure and a rise in the diastolic pressure (Chart I.); and improvement clinically began at once. After two months' treatment he could walk two miles up a slightly rising gradient without any difficulty, and he improved so much that the treatment was stopped for a period of eleven weeks, when it was found that his pressure had gone up to 230 mm. Hg. At the same time he was more short of breath on exertion and had had one or two attacks which were suggestive of cerebral claudication with severe headaches.

He was admitted to the ward for diathermy. The headaches disappeared during treatment, and, though the blood pressure was slightly reduced after each treatment, the average remained in the region of 230 mm. Hg. Subjectively he felt very much improved; his headaches had almost disappeared.

*Case* 2. A female, aged 70, with a blood pressure of 200/100 mm. Hg., a normal electrocardiogram and who had suffered clinically for the last three years from numbness and coldness of the hands and arms and was unable to do any household work during this period. She was given diathermy from wrist to wrist twice a week for a long period, with a current of ½ to ¾ of an ampere. The blood pressure fell to 130/90, while clinically there was marked improvement. She became warm and remained warm and no longer suffered from the numbness and coldness of her hands and arms. She was now able to carry on her household duties without any trouble and clinically had improved remarkably.

### The Effect of Diathermy on Angina Pectoris

The technique consists in passing the current through the chest between the front and the back, one electrode (7 in. by 3 in.) being placed horizontally between the shoulders behind, while the other electrode, also 7 in. by 3 in., is placed across the front of the chest at the level of the third rib. At first a current of half an ampere for a few minutes is used, but later the current is increased to 1 ampere and the time extended to half an hour as the patient gets used to the treatment.

The effects of the treatment varied with the type of angina pectoris which was present, and for the purpose of comparing the results these cases were divided into groups :—

(1) *Angina of Effort*

(*a*) Those with high B.P., *i.e.*, over 150 mm. systolic pressure.

(*b*) Those with low B.P., *i.e.*, under 150 mm. systolic pressure.

(*c*) Those in which the angina of effort followed an attack of coronary thrombosis.

(2) *Vasomotor Angina or Pseudo-Angina*

I. ANGINA OF EFFORT. It is in this type of cardiac disability that diathermy is of the greatest help ; the patients, usually elderly, are seized with a severe retrosternal pain of an " arresting " or " gripping " type which brings them to a stop when they undertake any exertion, usually walking.

The amount of exercise necessary to induce the pain varies considerably in different individuals, and in its severer forms the patient can only walk 30 or 40 yards without bringing on the pain ; he is often spoken of as " a 50 yards' man " or " a 100 yards' man," as the case may be.

It is believed that this pain is due to ischæmia of the heart muscle brought about by the inability of the narrowed coronary arteries to supply the extra blood which is required by the heart muscle on exertion. The effect of diathermy in these cases is remarkable. After a few treatments the patients can walk farther than formerly without getting the pain ; the " 50 yards' man " becomes converted into " a 100 yards' man," and may even improve to such an extent that the pain on effort entirely disappears. In this way the diathermy has brought about a marked increase in the cardiac reserve power of the heart. Speaking broadly, the beneficial effect seems to be more marked in cold weather than in warm.

How this effect is brought about is not definitely known and there are probably several factors at work. When the current passes transversely through the body, as it does when the electrodes are applied to the front and back of the chest, the skin and subcutaneous fat are heated most while the heart, owing to the low resistance and to the cooling effect of the blood, is only heated to a slight degree.

It follows, therefore, that a large measure of the beneficial effect is due to this "poultice-like" action of these tissues. Probably there is also a direct effect on the heart and coronary circulation, for it has been shown recently by Hyman (4) that striking changes in the "T" wave of the electrocardiogram may later take place when angina cases are treated with diathermy.

When one contrasts the newer "short-wave" diathermy with the older "long-wave" type, in the former, owing to better penetration, there is probably much less of the "poultice effect" and consequently more direct action on the heart and its circulation. It would appear that this is the explanation of the better results which are obtained in the treatment of angina with the "short-wave" therapy (Chapter XXV., pp. 342–346).

Of the three varieties of angina of effort, Group (*a*), the type with the high B.P., probably shows the best response of all to this treatment, with relief of the pain and a lowering of the average systolic pressure. Patients in Group (*b*), the angina of effort with a low blood pressure, also respond well but not so dramatically as do those of the former group, and the effect of the diathermy in lowering the blood pressure is of a much smaller degree.

Group (*c*), the angina of effort which follows on a recent coronary thrombosis, requires a fuller explanation. This is the type of pain which is a sequel of an attack of coronary thrombosis, the patient first becoming aware of the pain on effort when beginning to lead a more active life after being confined to bed during the more acute stage of the attack. This type of angina of effort tends of its own accord to diminish in intensity as the heart recovers from the attack and often it disappears without any special treatment. It is, therefore, very difficult to assess the value of diathermy in this variety of cardiac pain, and it must be remembered that here one is not dealing with a coronary artery which is narrowed as a result of spasm, but with a block due to a blood clot. It is not surprising, therefore, that diathermy is of less value and more variable in its action in this type of angina of effort than in any other. Many cases fail to obtain relief, while in those which do improve, one always feels doubtful whether the improvement is really due to the diathermy, or to the usual tendency of the pain to disappear when the heart has at length recovered from the original lesion.

II. Vasomotor or Pseudo-angina. This condition responds to diathermy in very variable ways. Its causation is quite different from that of the other varieties of cardiac pain that we have considered and therefore it is more protean in its symptomatology. Some cases appear to respond well, while in others it is very disappointing in its effect and it is impossible to predict with any degree of certainty what is likely to happen in any case. One can only try the effect of the treatment and continue with it in those cases which respond favourably.

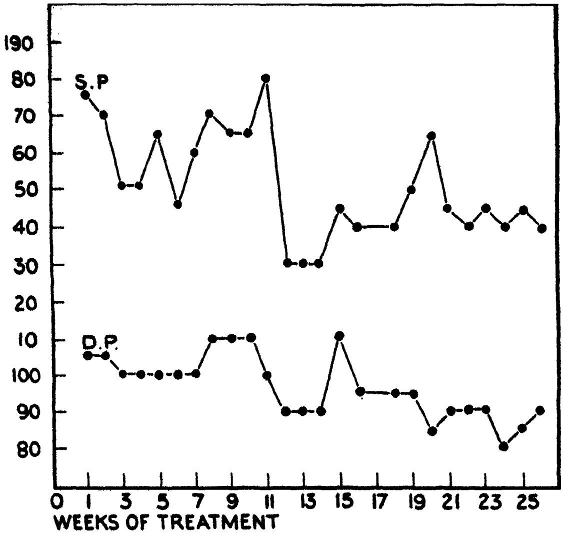

Fig. 87.—Chart II.

*Case* 3. A male, aged 70, with a six years' history of cardiac pain on exertion accompanied by some dyspnœa. Electrocardiogram showed left ventricular preponderance and a negative T. in lead I. Blood pressure was 175/105 mm. Hg. Clinically, he was a typical case of the angina of effort.

Diathermy was given through the chest three times a week with a current of about 2 amperes, the treatment lasting about half an hour. He improved considerably so that he could walk without effort and was able to play bowls for four or five hours without any discomfort. As will be seen (Chart II.) there is a definite fall in the systolic and diastolic blood pressures. After a period of improvement the treatment was stopped and his blood pressure began to rise again. Under a second course of diathermy he improved again and at the end of treatment was very much improved and his blood pressure had fallen to normal.

*Case* 4. A male, aged 51, was clinically suffering from the angina of effort with a six-months' history. His electrocardiogram showed slight left ventricular preponderance with a bizarre Q.R.S.: his blood pressure was 150/80 mm. Hg.

The diathermy treatment was given three times a week. Each treatment lasted half an hour: 1½ amperes through the chest. A small fall in the systolic pressure occurred but his subjective sensations improved remarkably. He could walk with comfort and could walk to the hospital, whereas previously he had had to be brought in a car. After about six weeks' treatment the pain completely disappeared. The treatment was stopped for a period and at the end of four months he returned, as the pain had commenced again. After a further course of treatment the pain again disappeared and at the end of treatment he only got his pain if he undertook severe exertion.

*Case* 5. A male, aged 58, who was suffering from some aortic obstruction and regurgitation. Complained of a retro-sternal pain, on effort, which radiated upwards into the throat and occasionally down the left arm. It was accompanied by shortness of breath on exertion and the patient was compelled to stop walking at times owing to the pain. The pain rapidly disappeared on standing. His blood pressure was 120/75 mm. Hg.

The diathermy was given six days a week, each treatment lasting half an hour and a current of 1½ amperes was used, through the chest. The effect was rapid and striking; soon after he commenced treatment he felt so well that he stated that he "could climb the side of a house," and he was able to walk up hills without any discomfort. After treatment he was able to undertake a considerable amount of effort, such as lifting heavy luggage, without pain.

## Diathermy in Diabetic Gangrene

Nagelschmidt in his original paper drew attention to the value of diathermy in the treatment of diabetic gangrene and recorded a case in which considerable improvement occurred after four weeks' treatment.

I have had the opportunity of treating 4 cases of diabetic gangrene by means of diathermy combined with the usual administration of insulin. I think there is no doubt that these cases improve considerably; the limb becomes hyperæmic, the pulsation in the arteries is definitely increased, and often there is a very considerable relief of the pain which in some cases is one of the dominant features of the condition. Patients often find that after treatment the pain is so much relieved that sedatives are no longer necessary in order to obtain a good night's sleep. The line of demarcation round the gangrenous patch becomes better marked and, where the area of necrosis is small, separation may occur without surgical interference. In those cases where the area of necrosis is larger, diathermy still has its advantages in improving the nutrition and vascularity of the tissues above the necrosed area, so that later on, when amputation has to be performed, the vascularity is so very much improved that it is unlikely that any necrosis in the flaps will occur subsequently to the operation. If the gangrene tends to be of a very moist type, occasionally diathermy will aggravate this condition, but as in most of the cases one sees the gangrene tends to be of a fairly dry type, this disadvantage is not frequently met with. In each case we have attached the electrodes to both feet of the patient and usually a current of 1 ampere has been passed for about half an hour, two or three times a week.

### Diathermy in Raynaud's Disease

Diathermy is one of the most valuable methods available for improving the peripheral circulation. It is not surprising, therefore, that it is frequently used in the treatment of Raynaud's disease for this purpose. I usually combine this treatment with frequent intramuscular injections of Padutin as well as calcium by the mouth.

After a course of treatment there is a considerable improvement in the circulation ; the cyanosis tends to diminish and this improvement tends to persist between each application. There is also a diminished tendency for the small patches of necrosis at the tips of the fingers to occur. The effect of the diathermy on the circulation can be illustrated by a recent case of Raynaud's disease in a girl, aged seventeen, who not only had the marked cyanosis and slight areas of necrosis at the tips of the fingers, but had also calcified deposits situated round the elbows, near the tips of the fingers and in the toes—a condition known as cutaneous calcinosis or dermolithiasis, in which the deposits of calcium occur, not as a result of increased calcium in the blood, but in consequence of slow capillary circulation. She had an extensive course of diathermy and Padutin injections. Under this treatment the cyanosis became very much less and the areas of calcification diminished markedly in size, and in one or two of the areas they completely disappeared.

I do not think that diathermy can replace sympathetic ramisectomy for the severe cases, but it certainly has an established place in the treatment of the milder degrees of this condition.

### Diathermy in Intermittent Claudication and Thrombo-Angiitis Obliterans

Intermittent claudication was one of the earliest conditions to which diathermy treatment was applied, and as it depends essentially on narrowing of the lumen of the arteries one would expect diathermy to have a marked effect. In this condition where the subjective symptoms are comparatively clear cut it is very easy to assess accurately the value of any treatment within a short space of time. I think there is no doubt that most cases of intermittent claudication are markedly improved by diathermy, and all the patients who were treated experienced almost immediately some relief from their symptoms, and after a fairly extensive course of diathermy the condition either disappeared completely or was markedly improved.

*Case* 6. A female, aged 65, who had suffered for the last twelve months with severe pain in her legs, aggravated by walking and relieved by resting. She was unable to walk more than 50 yards without having to stop owing to the pain. She had no enlargement of her heart, but had marked arteriosclerosis : blood pressure 170/75 mm. Hg. Her legs tended to be cold even when lying in bed unless kept warm by a hot-water bottle.

She was given diathermy treatment three times a week from ankle to ankle and also injections of Padutin. The pain began to improve rapidly under this treatment and in five weeks she was able to leave hospital free from pain.

*Case* 7. A male, aged 63, with pain in the legs which occurred on exertion, chiefly walking. This pain, as a rule, came on after walking about 100 yards and compelled him to stop. There was marked arteriosclerosis, slight cardiac enlargement; his blood pressure was 170/95 mm. Hg.

Diathermy treatment was given: ¾ of an ampere to both feet. There was an almost immediate improvement in his condition and soon he could walk without getting any pain. His blood pressure dropped to 140/80 mm. Hg., and he was able to return to his work as an engine driver.

I have only had experience of treating 1 case of thrombo-angiitis obliterans with diathermy :—

*Case* 8. This was a case of a man, a Russian Jew, aged 51, who had resided in this country for twenty-six years. While in Russia he often ate black bread, but since he had been in England he had then chiefly white bread, though he occasionally ate some black.

In 1915 he had his left leg amputated owing to a large ulcer which failed to heal. For the last five years he had pain over the præcordium when walking and about three years ago he had sudden transient attacks of blindness in the left eye. He also complained of pain in his right leg and in both arms at times. There was marked arteriosclerosis, his radial pulses were palpable but the pulse could not be felt in his right foot: his blood pressure was 220/130 mm. Hg.; his electrocardiogram showed a fundamental normal rhythm with auricular premature beats. His blood Wassermann was negative. The pain was so severe that he had to have many injections of morphia.

He was put on diathermy through both arms and through his leg—current of 1 ampere. This relieved to some degree his symptoms of pain but it did not in any way stop the progress of the disease and he ultimately died about a year after first coming under treatment.

## REFERENCES

(1) Nagelschmidt, F. *Archives of Roentgen Ray*, 1912, XVI., No. 9, p. 334.
(2) Hutchison, R., and Sherren, J. "Index of Treatment," 8th edition, p. 86.
(3) Hay, J., and Ince, P. *Lancet*, October 16th, 1926, p. 799.
(4) Hyman, A. S. *Arch. Phys. Ther.*, 1933, XIV., No. 5.

# CHAPTER XVIII

## MEDICAL DIATHERMY IN THE TREATMENT OF DISEASES OF THE NERVOUS SYSTEM (EXCLUDING DEMENTIA PARALYTICA)

In disease of the nervous system diathermy is most commonly utilised and has obtained the largest measure of success in the malady commonly diagnosed as peripheral neuritis. It is frequently able to procure relief of pain after simpler methods of treatment have failed. It is successful also in some resistant cases of other pain-producing diseases of the nervous sytem, such as tabes dorsalis and intercostal and post-herpetic neuralgia. In cases of paralysis, more particularly when groups of muscles are denervated, the accompanying congestion and cyanosis can be relieved by diathermy and the subnormal temperature raised. For these reasons diathermic treatment is a useful accessory agent in the treatment of the cold blue limbs in cases of anterior poliomyelitis or injury of nerve trunks. In the last-mentioned diathermy may also be employed for the purpose of aiding the resolution of the inflammation following the trauma.

In the treatment of the above-mentioned diseases the diathermic current is administered *locally*. Diathermy appears to have some therapeutic power in cases of paralysis agitans. In the treatment of the cases of this disease hereinafter described the diathermic current was directed along the limbs, the object being to produce a mild degree of *general* diathermy.

Another disease of the nervous system, viz., dementia paralytica (general paralysis of the insane) is frequently treated by diathermy. The current is employed for the purpose of producing high degrees of general diathermy and obtaining the so-called therapeutic fever. The treatment of this disease by therapeutic fever obtained by the diathermic method forms the subject of the next chapter.[1]

### Peripheral Neuritis

The cases which respond best to diathermic treatment are those in which small areas of tenderness on pressure are discovered. When the patient complains of pain in the upper limb these tender points may be found in various situations, such, for example, as the vicinity of the upper angle or vertebral border of the scapula, the acromial angle, the neighbourhood of the tendon of insertion of the deltoid, the muscles in the vicinity of the internal or external epicondyle of the humerus, and elsewhere. When the patient feels pain in the occipital region it is common to find tender points in the sterno-mastoid or posterior nuchal muscles close to the mastoid process or occipital bones. When the pain is felt in the leg or thigh the tender points may be found in various situations, for example, in the following: just above or below the posterior portion of the iliac crest, the sacro-iliac region, the neighbourhood of origin of the hamstring muscles from the ischial tuberosity, the region of insertion of the biceps femoris, etc. Points of tenderness may also be discovered by exerting pressure on the bellies of muscles either in the neck or in the limbs. Tender nodules may also be found.[2]

#### *Methods of Application*

When the tender areas above mentioned are found the diathermy should be administered to them. If one alone is found a disc electrode measuring 2 in. or 3 in. in diameter is placed in position over it and the circuit is completed by means of a cuff electrode around the wrist or ankle. If more than one are discovered and they are close together it may be possible to cover them all with the same electrode. If they are farther apart the cuff electrode may be discarded and two active disc electrodes employed. Care must be taken that the two active electrodes are not close together when they are on the same aspect of the trunk or a limb.

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[1] The *inductothermic* method of procuring therapeutic fever is being increasingly practised. In time it may replace the *diathermic* method. Inductothermy is considered in Section IV.

[2] In cases where the tender spots or nodules above mentioned are discovered it is common to find that the area, or areas, of skin where the patient feels the pain do not correspond to the cutaneous distribution of one or more nerve trunks. When, in the same case, there is no wasting of muscle or trophic disturbance it seems unlikely that there is inflammation of a nerve trunk or trunks. It is more likely that the pain is due to inflammation of fibrous tissue away from the nerve trunk, the pain being referred to the skin along cutaneous nerves. In other words, the case is not one of neuritis, but rather one of fibrositis with referred pain.

When the operator can devote his whole time and attention to the patient it is a good plan to adopt the labile method of applying the diathermy (see p. 149). The advantages of this method have already been emphasised. In addition, it enables the operator to administer kneading movements at the same time as the diathermy. The stationary electrode which completes the circuit may be placed around the wrist or ankle, or alternatively, the patient may sit or recline on a condenser couch.

If no tender points are discovered one of the electrodes may be placed on the spine over the dorsal or lumbar enlargements of the spinal cord according to limb (upper or lower) in which the pain is felt. The other electrode is applied to the region of skin where the patient feels the pain.

The treatment should be given as frequently as possible, even twice daily if this can be done. When only one application can be made daily it should be given as late in the day as convenient, in order that the relief may be continued as far through the night as possible. If the periods of relief are short, or do not lengthen, the electrodes should be held in position for longer periods.

### *Results*

It is not uncommon for the patient to feel some aggravation of the pain *during* the application of diathermy. As soon as the part under the active electrode begins to get warm he will sometimes say that the heat has " brought the pain out." This is not an unfavourable sign. It soon subsides when the application is over, and considerable relief follows.

The patient seems to have no difficulty in distinguishing this temporary increase of pain from that which would be caused by undue heating of the skin. The former is often felt, in addition, in parts other than that under the disc electrode.

After the first application relief is felt for two to ten hours. Cases that are going to respond favourably and derive considerable or complete relief from a course of diathermy are comfortable for progressively longer periods as the course proceeds, and although the pain tends to return in the intervals between successive applications it does not attain its original severity. If the pain persistently returns with undiminished severity between each application the case is unlikely to derive much benefit.

It has already been stated that the increase of pain which is occasionally felt *during* diathermy quickly subsides after the application is over. Increase of pain which persists after the diathermy is, in the author's experience, extremely uncommon. In other words, diathermy very rarely makes the patient worse. In one case of brachial neuritis, in a woman of fifty, the patient said that the pain gradually increased after the first application of diathermy and was so severe at midnight that her doctor had to give her "an injection." No other case of a similar kind has occurred in the author's experience.

Cases of neuritis in the upper extremity respond, on the whole, more favourably than those in which the neuritis is present in the lower limb. The probable reason for this is the inability of the patient to keep the lower limb at rest when he is coming for treatment. The upper extremity, on the other hand, can be kept at rest in a sling.

Cases of long duration, *i.e.*, a year or more, are difficult to relieve, at any rate permanently, by diathermy alone. This is especially the case with neuritis of the sciatic nerve. Adhesions may have developed—in these cases—between the nerve and the hamstring muscles. Treatment more heroic than diathermy should then be applied, such as strong vibratory massage or the production of powerful rhythmic twitches of the hamstring muscles, either by the static wave current or the slowly interrupted faradic current.

Such treatment, however, is considerably more effective if each application is preceded by diathermy.

At the onset of sciatica, or of neuritis elsewhere in the lower extremity, especially if the pain is severe, it is questionable whether it would be wise for the patient to receive diathermy if a journey were rendered necessary. The benefit that would be derived from the treatment might easily be nullified even by a short walk. The author treated a case of sciatica soon after its onset, and although each application caused great relief no permanent progress was made. Eventually the case became worse and the patient was compelled to stay in bed.

Untoward results of this kind, however, do not always occur. At the request of his doctor the author treated a case of sciatica, in a gentleman aged fifty-five, accompanied by severe pain. The treatment was commenced on the sixth day. The patient walked with the help of a stick, with his knee slightly flexed and his heel off the ground. After receiving the first application the pain was so much relieved that he was able to walk naturally, and without pain, from the room, down a long passage and enter his car. This treatment was given at 5.30 p.m. The pain returned about midnight and became severe during the small hours of the morning. Diathermy was repeated daily for five days. Each application was followed by great relief, but with subsequent recurrence in the early hours of the morning, though with less severity. On the fifteenth day the pain was slight. The patient made a complete recovery. The pain had not returned after ten years.

The opportunity of treating a case at its actual onset is rarely obtained, but it occurred in the following case. The porter in attendance at the the author's clinic was noticed to develop a limp one afternoon while at work. He complained of pain in the back of his hip and knee. A diagnosis of sciatica was made. Diathermy was administered each morning and afternoon. The patient derived considerable relief and was able to perform his duties each day. Although the pain returned each night its severity gradually lessened. After eleven days it disappeared entirely. There has been no return during the subsequent twelve years.

The major number of the cases which have been received, however, were those that had already received fruitless treatment by drugs and external applications of anodynes or counter-irritants. Recent and severe cases should be advised to rest in bed until the acute stage has passed.

In the table on p. 267 are given the particulars of 10 consecutive cases of brachial neuritis which were treated by the method described above. They give an idea of the results that may be obtained in the routine treatment of this malady by diathermy.

On p. 268 are given particulars of 14 consecutive cases of sciatica which were treated by diathermy.

### Other Pain-producing Diseases of the Nervous System

Of other pain-producing diseases of the nervous system the author has had a small but successful experience in *tabes dorsalis* and *intercostal neuralgia*. The lightning pains which may occur in the first mentioned were relieved by diathermy. One electrode was placed on the vertebral column over the site of the lesion in the posterior roots of the spinal cord; the other was applied to the periphery where the pain was most acute. Great care should be exercised in the treatment, because the patient may be unable to perceive the sensation of heat. The current should be increased slowly and the skin should be heated a slight degree only.

Diathermy is sometimes successful in abolishing the pain which often persists after herpes zoster.

A patient of 65, a carman, felt pain in his shoulder and arm. A few days later a rash appeared in the same region, and pain became very severe. Erythema was visible in the area where pain was referred and some minute red spots were seen. Diathermy was applied by way of electrodes placed on the forearm and on the spine in the region of the cervical enlargement of the cord. Treatment was given twice weekly. Relief was felt after the first application. After a month the pain was completely abolished.

Other cases also have derived considerable relief. In these the pain had not been of long duration. Patients in whom it had persisted for many months derived little or no relief from diathermic treatment.

The writer has treated 4 cases of *trigeminal neuralgia* by

| | | Duration of Complaint. | No. of treatments. | Result. |
|---|---|---|---|---|
| Case 1. | Female, 37 | 3 months | 12 | Severity of pain reduced by diathermy after ionization had failed. Pain was not entirely abolished, and slowly returned after patient discontinued treatment. |
| Case 2. | Female, 25 | 2 weeks | 16 | Relief of pain commenced at once and lasted for increasingly long periods after each treatment. Recurrence of slight pain after work was resumed, but at end of course it disappeared. |
| Case 3. | Male, 42 | 4 months | 16 | Relief commenced at once. At end of course pain had entirely disappeared. |
| Case 4. | Male, 33 | 2 years (intermittent) | 12 | Gradual reduction in severity of pain. At end of course was felt only slightly on violent movement of arm. |
| Case 5. | Female, 50 | 7 months | 5 | Diathermy produced relief for one hour only after each treatment. |
| Case 6. | Male, 51 | 10 weeks | 10 | Diathermy produced temporary relief and the pain was lessened, though not completely abolished, at end of course. Ionization had been tried for four weeks without avail before the diathermy. |
| Case 7. | Female, 34 | 8 weeks | 16 | Improvement commenced at once, and pain was soon reduced to a slight degree, but could not be entirely removed. |
| Case 8. | Female, 65 | 6 months | 8 | Relief slight and short after each treatment ; no permanent reduction in severity of pain. |
| Case 9. | Female, 20 | 1 week | 15 | Complete relief at end of course. |
| Case 10. | Female, 38 | 6 months | 10 | Complete relief at end of course. Pain returned six months later. A second course of diathermy abolished the pain for twelve months. Patient is now under treatment for the third attack. |

| | Duration of Complaint. | No. of treatments. | Result. |
|---|---|---|---|
| Case 1. Male, 38 | 7½ years (intermittently) | 4 | Relief for about twelve hours, when pain returned with undiminished severity. |
| Case 2. Female, 48 | 4 weeks | 3 | Relief for some hours, pain returning with much less severity. |
| Case 3. Male, 55 | 3 weeks | 8 | Relief for gradually lengthening periods. Pain was not entirely abolished. Ionization eventually completed cure. |
| Case 4. Male, 33 | 5 months | 4 | Pain reduced to slight degree. |
| Case 5. Female, 28 | 6 months | 7 | Complete freedom from pain for twelve hours or longer. Pain could not be entirely abolished by diathermy. |
| Case 6. Female, 63 | 5 years (intermittently) | 7 | Slight and temporary relief. |
| Case 7. Male, 48 | 3 months | 12 | Relief of pain for a few hours. Pain was only slight at end of course. |
| Case 8. Female, 19 | 3 months | 12 | Gradually increasing relief for lengthening periods Slight "stiffness" in leg at end of treatment. |
| Case 9. Male, 58 | 5 weeks | 5 | Slight relief of pain at end of course. Further relief after ionization. |
| Case 10. Male, 53 | 10 months | 7 | Slight relief from diathermy. Previous applications of ionization and sinusoidal current were ineffective. |
| Case 11. Male, 45 | 2 weeks | 4 | Considerable relief of pain. Further improvement by ionization. |
| Case 12. Male, 19 | 3 weeks | 5 | Slight relief. Further improvement by ionization. |
| Case 13. Male, 56 | 3 months | 11 | Great relief from diathermy. Pain only slight at end of course. Ionization with quinine and salicylic ions had been previously tried and found ineffective. |
| Case 14. Female, 54 | 2 years | 12 | Diathermy produced relief after sinsuoidal current failed. Duration of relief increased till pain became slight. Six weeks after treatment ceased the pain returned and was somewhat severe. |

diathermy. In these cases there was no evidence of any source of irritation in the region supplied by the nerve. The results were disappointing. By reason of the success that may be obtained by means of a galvanic current of high intensity the writer has abandoned further trial of diathermy for the treatment of trigeminal neuralgia.

If, however, a site of inflammation is discovered in any part of the territory supplied by the sensory fibres of the nerve it may advantageously be treated by diathermy and the neuralgia may disappear. One of the writer's patients was freed after the application of diathermy to the maxilla.

## Diathermy in Paralysis

Professor Bordier, of Lyon, has called attention to the therapeutic powers of diathermy in infantile paralysis. The object of the treatment is to raise the temperature of the cold paralysed extremities. Progress in paralysis is greatly retarded by cold. By reason of its ability to heat the deep as well as the superficial structures of the limbs, diathermy is an ideal method of raising the temperature of the paralysed extremities. The latter retain some of the warmth imparted to them by the current even as late as twenty-four hours after the treatment.

To apply diathermy a large plate electrode should be applied to the patient's back and connected to one of the terminals of the machine. The other electrode should be applied to the sole or palm according to the extremity affected. If necessary an electrode should be placed on each sole or palm and both electrodes connected to the other terminal of the machine. A watch should be kept on the patient and the current maintained at a strength that keeps the legs or arms comfortably warm. An alternative method is to replace the palm or sole electrode by a padded disc and stroke the latter slowly and rhythmically along the extremity over the various muscles.

The author does not think diathermy can replace treatment by the rhythmically varied sinusoidal current in full-length baths. It is, however, a valuable additional treatment, particularly when the paralysed limbs are very cold and cyanosed, especially in the cold months. It is possible, also, that the slight elevation of temperature of the trunk may relieve congestion and improve the circulation in the spinal cord.

### Paralysis Agitans

The severest test for a new method of treatment is applied when the treatment is tried for diseases for which no known methods are successful. The disease in which, in the writer's experience, the test has shown the nearest approach to success is paralysis agitans. Cure or *permanent* relief has not been obtained, but in some cases a considerable degree of relief may be procured, and the improvement may be maintained for some months.

Diathermy should be administered in a manner that will elevate the temperature of the entire body. In other words, the diathermy should be *general*. Efforts should be made to raise the internal temperature to 100° or 101° F. The patient should be recumbent on a couch and covered with rugs or blankets so as to reduce loss of heat as much as possible.[1]

The following are the particulars of the cases originally treated by the writer.

*Case* 1. Female, aged 55. This patient had suffered for two years from progressive weakness of the right hand and arm and tremors. Walking had induced early fatigue. Various forms of electrical treatment had been tried, including cerebral galvanism, which had been applied by the late Dr. Lewis Jones. On February 10th, 1914, treatment by diathermy was commenced. The current was directed along the upper limbs, and its strength was sufficient to cause a rise of temperature of the whole body. The patient sweated freely during the application of the current. Treatment was given twice weekly.

On February 13th she felt better in general health. On March 3rd she was able to resume knitting and needlework, and she could write more steadily and with less fatigue.

On April 17th the treatment was discontinued. The improvement in general health was maintained during the course of treatment, and headache, which had been constant before, was abolished. The tremors did not cease, but manual work could be undertaken with less fatigue and skilled movements could be performed without much difficulty.

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[1] Methods of producing general diathermy are described on pp. 155–157. Ambulatory cases can be treated by these methods. Paralysis agitans is now being treated by subjecting the patients to higher degrees of heat obtained by means of the inductothermic method. This is described in Section IV. It cannot be practised on ambulatory cases.

The benefit resulting from the diathermy was maintained for six months. A second course of treatment was commenced, but could not be completed as the patient left London. No communication from her was afterwards received.

*Case* 2. Female, aged 56. She was an in-patient at St. Bartholomew's Hospital, under care of the late Sir Wilmot Herringham. Her chief complaints were the weakness of her arms and legs and inability to do fine work with her hands. General diathermy was commenced on July 3rd, 1914. Eight applications were made. On July 20th the patient went away for a holiday, and treatment was suspended. The improvement during the treatment was great, and was especially noticeable in the gait, and the patient said she could walk without "scuffling." On September 17th she returned and reported that she had maintained her improvement.

In May, 1915, treatment was resumed on account of recurrence of symptoms. The subsequent history was not obtained.

*Case* 3. The patient was a doctor, aged 66, who had retired from practice some years before the onset of the disease. He complained of a general weakness and difficulty in walking.

A long course of treatment could not be given on account of the length of the journey which he had to undertake. He said that he felt much better after the diathermy. The briskness of his movements was evident after each application, and he was able to walk at an increased pace. The improvement was maintained for a few months, but eventually the patient was confined to his room owing to increasing weakness, and he died at the age of 70.

*Case* 4. Male, aged 65. He had noticed tremors of his hands for many years, but of late they had been more evident. He had felt some difficulty in walking during the past few weeks and a tendency to fall forwards.

General diathermy was commenced on December 13th, 1918. Twelve applications were made in thirty-four days. At the end of this time there was no evident alteration of the gait or lessening of the tremors. The patient said that he felt much better in general health. Six months later he desired a repetition of the treatment. Before he was able to make plans mental symptoms ensued, and the patient became violent at times, so that detention under observation was necessary.

Another case received general diathermic treatment at intervals over a period of three years (1925–26–27). The symptoms from which he sought relief were vocal huskiness and difficulty in commencing to articulate. Involuntary tremors of the hands and fingers were persistent. During the period mentioned the disease appeared to have remained stationary. After each course of treatment the patient felt better and articulated more easily.

All the cases above described were in patients older than fifty-four. Other patients were treated; 2 were men of thirty-nine and forty-nine respectively, and 1 was in a woman of thirty-one. These derived no benefit. It seems, then, that diathermy was successful only in elderly patients. This opinion has been confirmed by further experience. Patients under fifty derive no apparent benefit.

Patients suffering from encephalitis lethargica and presenting the Parkinsonian syndrome do not seem to respond to diathermy. A youth of twenty-four was treated twice weekly for nine months. Although he was brighter and less lethargic at the end of this time the improvement might have occurred in spite of the treatment, seeing the lengthy duration of the course.

### Diathermy in Idiopathic Epilepsy

Writing in the August number, 1935, of *Klinitcheskay Meditsina*,[1] V. V. Issahyev reported the results he had obtained in the treatment of 24 cases of epilepsy by diathermy. The frequency of the attacks and their severity were diminished. The general health of the patients improved. Attacks were never provoked by the treatment. The technique was the following. One electrode measuring about 6 cm. by 12 cm. was applied to the nape of the neck. This was connected to one terminal of the machine. The other terminal was connected to two smaller electrodes, one being placed on the forehead and the other on the epigastrium. A current of 400 to 1,000 milliamperes was passed from ten to twenty minutes, on alternate days. A course of treatment comprised eleven to twenty sessions. Intervals of three to four months elapsed between successive courses.

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[1] *Brit. Med. Jour.*, November 30th, 1935 ("Epitome of Current Medical Literature").

# CHAPTER XIX

## MEDICAL DIATHERMY IN THE TREATMENT OF GENERAL PARALYSIS (DEMENTIA PARALYTICA)

BY
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### INTRODUCTION

SINCE Jauregg's first report in 1918 on the treatment of general paralysis by malaria much research work has been done on the employment of pyrexia as a therapeutic measure. Relapsing fever, sodokn fever, the fever produced by injecting such substances as typhoid vaccine, tuberculin and solutions of sulphur in olive oil, have all been employed and have been found to produce comparable results, but with these, as with malaria, there is difficulty of control once the treatment has been initiated. There is increasing evidence in support of the view that the heat produced by the fever is the main, if not the only, factor in producing a remission in cases of general paralysis of the insane. Experiments on the effect of heat on the spirillum pallidum *in vitro* and on syphilitic lesions in rabbits have been reported from time to time. The thermal death time of the treponema pallidum *in vitro* was found to depend on two main factors, the degree of elevation of the temperature and the duration of its maintenance. A temperature of 104° F. sustained for three hours, or 106·7° F. for one hour, sufficed to destroy this organism. Temperatures varying from 105·8° to 108° F. not only prevent the development of syphilitic infections in rabbits but also render syphilitic lesions sterile; the lower temperature requiring to be maintained for a longer duration than those higher in the scale.

Attempts to raise the body temperature by physical means have been made. Neymann, of Chicago, aware of the fact that the diathermic current produced heat in the body tissues, endeavoured to heat up the brain of a paretic by local diathermy. This was found to be impracticable. Experimenting on dogs, he found that with electrodes placed on the back, abdomen and chest, and employing large amounts of current, the body temperature was rapidly raised. Applying the same technique to man he found that with suitable electrodes and thorough insulation the body temperature could be raised to the desired height and its further rise or fall kept under complete control. By this means, cases of general paresis were caused to undergo periodic bouts of pyrexia simulating those resulting from malaria. Other experimenters, employing hot-water baths, found it was possible to raise the body temperature, and cases of general paresis have been treated in this way with success. This method calls for good co-operation on the part of the patient and has never become popular. Hot-air baths, too, have been employed for the same purpose. The common factor in all these methods is pyrexia induced by physical means.

## TECHNIQUE

Various types of electrodes may be used. Neymann still adheres to his original models somewhat modified. The writer finds that collars made of fine copper gauze (mesh 32 to the inch) are most suitable. These collars are about 5 in. broad and of assorted lengths. One collar is adjusted round the chest and one round the upper part of each thigh. The edges of these electrodes are turned over for about a depth of ½ in. and bound with thin mackintosh sheeting; a backing of the same material, slightly wider than the electrode, is attached to the latter in its middle third. From the chest electrode a lead goes to one terminal of the machine. The leads from the thigh electrodes go to a coupling and thence to the other terminal. Each electrode is securely fixed to the body by means of a many-tailed bandage, the ends of the electrode and of the backing being made to overlap. To prevent loss of heat, the patient may be placed in a good insulating bag, or be covered with blankets. If the latter method is adopted a bed is made up with a mackintosh sheet and three blankets *below* the patient; four blankets, a mackintosh sheet, and then two more blankets are placed *over* him, all being well tucked in at the sides and at the foot of the bed. The shoulders and throat should be covered by an additional small blanket or towel. The insulating bag is much more satisfactory, providing as it does equally good insulation and greater comfort for the patient. These bags are constructed of two layers of waterproofed cotton drill separated by insulating material, and are fixed along one side. The other side and both ends are zipp fastened. The bag is thus capable of being fully opened for cleansing purposes. Two coverings of Terry cloth suffice to absorb all sweat that may be excreted. A Lawson Tait bedstead with adjustable head and knee supports is found to be more suitable than the ordinary bed because some patients like to have their positions altered from time to time. It is advisable to have the pillows covered with mackintosh sheeting to prevent soakage of sweat. The patient should receive an enema the previous night and be allowed only a light meal in the morning prior to undergoing the treatment. Before the electrodes are adjusted and fixed the area of the underlying skin should be smeared with a good lubricating jelly. The electric rectal thermometer may or may not be used; if used, it tends to add to the patient's discomfort. It is perfectly satisfactory to take the temperature in the axilla once every half hour until the temperature is well up, and then every fifteen minutes until the period of defervescence.

The leads having been connected, the current is turned on and allowed to rise gradually to 2·5 amperes. Should there be any complaint of tingling or burning, an examination of the electrodes must at once be made. The rate of rise of the temperature will depend on the physique of the patient, the thoroughness of the insulation and the temperature of the room. The average time taken to reach 104° F. is two and a half hours. At this stage the current should be reduced to 1 ampere and any further adjustment be determined by the course of the temperature curve. After the temperature has been maintained for four hours at or above 104° F. the patient should be gradually cooled by removal of one or more blankets, or by slightly opening one side of the insulating bag. During the treatment profuse sweating takes place and the blood and body tissues suffer loss of chlorides. To replace this loss frequent sips of 0·6 per cent. saline should be permitted. Loss of weight varying from 3 to 13 lb. takes place, but is regained usually within a week. Further treatments at weekly intervals for eight to ten sessions complete a course. After each treatment it is advisable to keep the patient in bed for at least twenty-four hours.

## The Use of the Inductotherm in place of a Diathermic Machine

The inductotherm offers an alternative method for the production of heat in body tissues. It consists of a vacuum tube oscillator which generates an alternating current of very high frequency. From this generator a cable is led in two or three loops outside the insulating bag at about the level of the patient's diaphragm.

The bed requires to be made up with some care. Two half mattresses are placed on the ordinary mattress in such a way that a space is left of just sufficient size to permit the passage of the cable. This prevents the weight of the patient's body bearing directly on the cable and so eliminates the possibility of a local over-heating. Spring mattresses must not be used.

From one and a half to two hours is required to raise the body temperature to 104° F. and by altering the intensity setting this temperature may be maintained or altered as required.

This method of production of hyperpyrexia in the treatment of cases of general paresis has several important advantages over the older method of diathermy. Patients who have been treated previously by diathermy state that they experience much less discomfort when being treated by means of the inductotherm. This is no doubt due, in part, to the absence of the constriction caused by electrodes. The pulse rate infrequently rises above 150; there is less loss of weight and less subsequent exhaustion. The risk of burns is entirely eliminated if the bed has been correctly prepared. There is greater simplicity in application and operation and less strain on those in charge of the treatment.

The results of the treatment by hyperpyrexia produced by means of the inductotherm are similar to those obtained when the diathermy machine is employed.

### Immediate Effects

Although the majority of patients relax and sleep when the temperature gets above 103° F., many are extremely restless with consequent effect on pulse and respiration rate and with sudden and alarming rise in temperature. Omnopon-scopolamine has proved effective in controlling these cases and should be given immediately the patient shows signs of becoming uncontrollable. Burns do not occur if the electrodes have been properly applied. A troublesome patient if not carefully watched may cause some maladjustment of his electrodes with increased risk or burning. Herpes labialis is apt to occur after the first or second treatment. This can be prevented by giving the patient on the morning after treatment local ultra-violet radiation. Typical seizures occur infrequently and necessitate the immediate cessation of the treatment and lowering of the temperature. Twitching of the facial muscles and nystagmoid movements of the eyes have been observed from time to time. Nausea and vomiting during the period of defervescence, or afterwards, occur if insufficient saline has been ingested. The feeling of lassitude, which supervenes on each treatment, disappears within twenty-four hours. If for any reason it becomes necessary to reduce the temperature urgently, this can be done rapidly and effectively by wrapping the patient in sheets wrung out of cold water, cold compresses being applied simultaneously to the head and neck.

### Therapeutic Results

The value of this method of treatment can be estimated by the number of cases that are enabled to resume their previous occupation.

Of a group of 82 unselected cases of general paresis, in whom pyrexia had been induced and maintained for over forty hours by means of diathermy, 28 (or 47 per cent.) have been discharged from hospital and, of these, 28 (or 34 per cent. of the total group) have been continuously employed since discharge, some for over four years.

The best results are obtained in patients who have been early cases of the disease.

Diathermy and inductothermy offer a safe, easily controlled and inexpensive method of treatment of general paresis. Its main drawback is the time consumed, as each session takes eight hours, during which the patient must be under the continuous observation of a specially trained nurse. A complete course of eight to ten sessions can be given in the space of three months.

## CHAPTER XX

## DISEASES OF THE ALIMENTARY SYSTEM

THE diseases of the alimentary canal which respond most satisfactorily to diathermic treatment are anal fissure and proctitis. Pain accompanying hæmorrhoids can often be relieved. In a few cases presenting the symptoms of mucous colitis the writer has had success but not in ulcerative colitis. Good results have been claimed by certain investigators for diathermic treatment of cholecystitis, peritoneal adhesions and atonic dilatation of the stomach with hypochlorhydria.

### Anal Fissure

The treatment of this painful affliction by diathermy is frequently successful. High-frequency currents, capable of producing diathermy, have been used for many years by French workers for the treatment of anal fissure, and cures have been reported in the large majority of cases.

The reasons for the success are doubtless the following. The diathermy lessens the contraction of the sphincter and probably abolishes the spasm of the muscle. The heat accelerates the blood supply to the region and aids the healing of the fissure. Drainage is accelerated. This is shown by the fact that the patient notices moisture or exudation from the anal orifice after the treatment.

To conduct the treatment the patient should lie on his side. A belt electrode should be secured around the pelvis. The active electrode consists of a handle made of ebonite, to the end of which is attached a conical metal end-piece. The latter is warmed and lubricated with boracic ointment. Its tip is pressed against the anus or, if the patient can tolerate it, introduced just within the sphincter. The current is started and slowly increased until the patient feels the sensation of warmth. Gentle pressure is maintained.

After two or three minutes the electrode will be felt to pass a little farther within the sphincter. The current should then be increased, but no more than is sufficient to procure gentle warmth. The electrode should be passed as far as can be effected without pain. Directly any pain is produced the electrode should be partly withdrawn until the pain disappears. The current should pass for twenty minutes and the treatment be repeated daily.

Relief is quickly obtained. In early cases the fissure soon heals and the pain is no longer felt. In long-standing cases diathermy may not procure complete relief because the fissure does not heal. In cases of this kind the fissure may be made to heal by zinc ionization. The last-mentioned treatment will cause the patient less pain if it is preceded by diathermy.

### Chronic Proctitis

The writer has employed diathermy in the treatment of 6 cases of proctitis in which the infecting agent was the gonococcus. Five were in males and the remaining case was in a woman. Gonococci were discovered in all the cases.

One of the patients (XI. 346), aged twenty-two, acquired the infection in 1934. His chief symptom was an irritating discharge. In spite of treatment by rectal irrigation the organisms were recovered. A course of rectal diathermy was commenced. After eight bi-weekly applications no gonococci were found. The discharge was still present but the patient said it was smaller in amount. Proctoscopic examination was made. It revealed some inflammation but the appearance showed marked improvement. After a second course of diathermic treatment there was a slight discharge and the proctoscope showed a few bleeding points on the rectal mucosa. Gonococci were not found. Treatment of the rectal mucosa by zinc ions then was instituted. The discharge disappeared and no more irritation was felt. The proctoscopic appearance was normal.

Another patient (XII. 13), aged forty-eight, was infected in August, 1935. Rectal pain became severe. Discharge and occasional bleeding occurred. Then the right ankle became painful and swollen. He was treated by protargol and vaccines. Three weeks after the onset of the symptoms he was sent to the writer for diathermic treatment. After the fifth séance there was no pain in the ankle or rectum, the bleeding ceased and the discharge grew less. The treatment was continued twice weekly. After the eighth application it was dropped for three weeks because the patient was compelled to stay at home on account of the development of "acute gout." The treatment then was resumed and continued until the end of the year. All the symptoms disappeared and the rectum regained its normal proctoscopic appearance.

The remaining male cases were treated by irrigation and by vaccines as well as by diathermy and occasionally by rectal ionization. It is difficult, therefore, to judge the part played by diathermy. Complete recovery occurred in all the cases.

### Mucous Colitis

In the following account the name "mucous colitis" is used for a malady in which the complaint of the patient was undue frequency of the desire to go to stool and passage of loose slimy fæcal matter and sometimes of mucus alone. All the patients treated by the writer were of the female sex and all except one were in their twenties. The remaining patient was fifty-five. All of them responded well to the treatment. At the end of the course the consistency of the stools (according to the patients' statements) was the same as before the onset of the trouble, and they were passed not more frequently than once per day.

One of the first 3 cases which the writer treated received diathermy at the suggestion of Dr. Harvey Kellog, of Battle Creek, Michigan, who was in London at the time and visited the electrical department of St. Bartholomew's Hospital. The following are the particulars of the case.

The patient, a girl of 26, came for treatment in the summer of 1926. She said that she had always passed frequent loose stools, and during recent months had passed nine or ten a day. She was pale and thin and her face was covered with the rash of acne vulgaris. Her menstrual periods had always been painful. She suffered from "train sickness" and needed the help of a friend to make the journey to the hospital.

Diathermic treatment was administered first by way of electrodes applied to the exterior. Little improvement of the patient's condition when both electrodes were situated externally. A rectal electrode then was introduced, and the circuit completed by a lead belt, placed around the exterior of the pelvic region. Slow improvement commenced, but she acquired influenza and relapsed. When treatment was resumed she improved rapidly. In March, 1927, her complexion was clear, the stools normal and passed once only a day, and the dysmenorrhœa from which she had suffered, had ceased. She no longer suffered from "train-sickness."

Two years later a message was received from her to say that she was in good health and had had no return of her trouble.

Another case which has been kept under observation to the present time (June, 1936) always responded well to diathermic treatment on each of the occasions when she had a return of the colitis. The following are the particulars of this case.

The patient, a girl of 24, consulted the writer in 1927, complaining of the passage of slimy material, sometimes fæcal in character, sometimes clear, often as frequently as once an hour during the day. After eight applications of diathermy by way of a rectal and pelvic belt electrode, the stools regained their normal consistency and were passed once a day. The symptoms returned in 1928, again in 1929 and 1934. On each occasion she received diathermic treatment and the results were as successful as those which followed the treatment first given. At the present time the patient is under similar treatment for the same trouble and progressing satisfactorily.

The case in a patient aged fifty-five was less severe. In 1929 and again in 1932 she suffered from undue frequency of defæcation, three to five times a day, passing loose slimy stools. Rectal diathermy procured normal frequency and the stools regained a firm consistency. No drugs were taken during the treatment and no rectal lavage was practised.

### Hæmorrhoids

Diathermy is an efficient form of treatment for the *pain* caused by hæmorrhoids. Some of the writer's cases remained free from pain for several months, and one patient, whose case is described below, was free from pain during the five years of subsequent observation. The treatment does not seem able to prevent prolapse or bleeding.

A suitable method of application is the following. An electrode identical with that illustrated in Fig. 77 is passed into the rectum and the circuit is completed by means of a belt electrode (Fig. 80, p. 192). The current should be strong enough to produce a comfortable degree of warmth. The thermometer should indicate about 105° F. Each application should last for twenty minutes and the treatment repeated twice weekly. The case which has been kept under observation for the longest period is that described below.

Male patient, aged 50. This patient suffered from prolapse in 1909. It was reduced. From 1911 to 1915 bleeding frequently occurred during defæcation. In February, 1917, the first attack of pain occurred, and extruding piles were noted. They did not disappear and were not replaced. From February, 1917, to June, 1919, there was constant aching pain. Frequent spasmodic pain was felt, not during defæcation, but during the latter part of the day. Defæcation did not cause pain.

On examination a number of firm fibrous pale hæmorrhoids were seen extruding from the external sphincter, and the mucous membrane was everted.

Diathermy was commenced on June 4th, 1919. Relief of the constant ache was noted at once, and the spasmodic pain became less frequent. On June 27th (after five applications) all symptoms had ceased. The patient reported at intervals since the cessation of the treatment and there was no recurrence during the next five years.

## Primary (Atonic) Dilatation of the Stomach

In some experiments conducted by Lüdin it was found that diathermy increased the peristaltic movements of the stomach. The movements of this organ, in a dog, were recorded and their increase was demonstrated. The stomach of a human subject which had remained almost full eight hours after taking a barium meal was, on another occasion, subjected to diathermy, and found to be nearly empty four hours after taking the meal.

To treat the disease by diathermy the patient should be in a recumbent posture. A metal electrode, measuring 6 in. by 8 in., should be applied to the anterior aspect of the trunk so as to lie over the stomach. The directing electrode, a little larger in area, should be placed on the opposite aspect of the trunk. The current should attain a strength sufficient to procure comfortable warmth of the skin and it should be allowed to pass for thirty to forty-five minutes.

Good results have been described by Bordier and by Setzu.[1] The latter made analyses of the gastric contents, after test-meals, in a series of cases and showed that the free hydrochloric acid and the total acidity increased after diathermy.[2] On the other hand, Lüdin was unable to obtain an increase, but showed that the peristaltic movements of the stomach were amplified.

### Peritoneal Adhesions

Pain due to intra-abdominal adhesions after operation has been successfully treated by Nagelschmidt, Turrell, Iredell and other workers.

Plate electrodes should be placed over the site of the adhesions and on the back. Lengthy séances of thirty to forty-five minutes are advised.

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[1] Setzu, *Riforma Medica*, Vol. 36, p. 125, 1920.

[2] The figures are quoted by Bordier in his work "Diathermie et Diathermothérapie," 1st edition, pp. 424 *et seq.* In the 6th edition Bordier refers (p. 551) to the work of Kanftheil and Lima, who found that the free hydrochloric acid and the total acidity were *diminished* by diathermy in cases of atony, gastritis, and gastric ulcer.

# CHAPTER XXI

# DIATHERMY IN THE TREATMENT OF DISEASES OF THE RESPIRATORY SYSTEM

It is in the treatment of lobar pneumonia that the largest experience has been acquired of the therapeutic action of diathermy in disease of the respiratory organs. Most of this experience has been gained in the United States, where diathermy is widely employed in the treatment of the disease mentioned. In England it is sporadically employed, but in one hospital—the West Middlesex—the routine treatment of lobar pneumonia is by means of diathermy.

Diathermy is sometimes employed in cases of pleurisy, chronic bronchitis and bronchial asthma.

## Pneumonia

The treatment of pneumonia by diathermy was suggested by Dr. Byron S. Price[1] in 1916. It has been fully investigated, since January, 1922, by Dr. H. E. Stewart, of New Haven, U.S.A. In the hands of the last-mentioned worker remarkably uniform and good results have been obtained in cases of lobar pneumonia. In almost every case the temperature began to fall *by lysis* directly after the first application of diathermy to the affected lobe. The duration of the fever was not shortened, but while it lasted the pain and the characteristic expiratory grunt disappeared. In almost all the cases the cyanosis disappeared. The rate of resolution appeared to be accelerated.

The possibility of the extension of pneumonia to other lobes did not appear to be prevented by diathermy, but the treatment was equally successful in the newly involved lobes.

In a series of 47 cases treated by diathermy in U.S. Marine

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[1] *American Journal of Electrotherapeutics and Radiology*, xxxiv, 445, September, 1916.

Hospital, No. 21, New York, the mortality was 17·1 per cent. In a series of control cases in the same hospital which were not treated by diathermy the mortality was 42·9 per cent. In a series of 22 private cases there was only one death. The youngest patient in the group was fifteen, the oldest eighty-two.

Equally favourable results of the action of diathermy in lobar pneumonia have been reported by Dr. Broesker of New Jersey, and by Dr. Westervelt of Pittsburg.

The electrodes employed by Dr. Stewart are flexible metal plates. They usually measure 7 in. by 4 in., varying according to the size of the patient and the number of lobes to be treated. They are cut to a size a little larger than the area of skin with which they are to make contact, thereby enabling their edges to be turned up and bent back. The cables from the diathermic machine are secured to the upturned edges. One of the electrodes is warmed, covered with hot soap lather and placed in position on the back of the chest over the affected lobe. A folded bath towel or a small pillow is placed against the electrode which is kept in position by the patient's weight. The other electrode, similarly prepared, is placed on the anterior aspect of the chest opposite the first. It may be kept in place by adhesive strapping or light sand bags. If the patient is restless and likely to change his position the electrodes may be kept in position by means of encircling elastic straps.

In the early stages of the disease when pain and dyspnœa are marked, Dr. Stewart advises a current of 1·4 to 2·0 amperes for twenty to thirty minutes every four hours. In the later stages he recommends a current of 1·0 to 1·6 amperes for the same time twice or thrice daily.[1]

A series of 20 cases of lobar pneumonia under the care of Dr. Morley Fletcher and Professor Fraser were treated at St. Bartholomew's Hospital, London, by Dr. G. Simon. He reported his method and results at a meeting of the Institute of Radiology on November 20th, 1930. The following account was published in the *British Journal of*

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[1] Those who are interested in the subject should consult "Diathermy, with Special Reference to Pneumonia," published by Paul B. Hoeber, New York City. Particulars are given of 159 cases.

**Radiology, May, 1931, and is reprinted by permission of Dr. Simon and the Journal mentioned.**

Robinson[1] recently published the results obtained at the West Middlesex Hospital, where he treated a large number of pneumonia patients with diathermy.

The results obtained at St. Bartholomew's Hospital were in keeping with Robinson's published results. From a study of the temperature, pulse and respiration charts, and the leucocyte count curves, there was no evidence of a specific response to diathermy.

Of course, in a certain number of cases, the temperature fell following the treatment, as was only to be expected in a disease with such a short and uncertain duration. In many cases, however, the general level of the temperature, pulse and respirations was unchanged during the time reckoned from the first treatment to the beginning of crisis or lysis. The complication of empyema often occurred in spite of diathermy treatment, even if it was continued after the crisis. No definite evidence is as yet available to show a definite decrease in the mortality from the disease.

Why, then, treat patients suffering from pneumonia with diathermy at all ? The answer to this is that there is one fairly constant response to diathermy, and that is, the relief of pain. Unfortunately the degree and duration of this relief is very variable. Sometimes it is complete and lasting, at others partial and transient.

In this series of cases, diathermy was of more value in the relief of pain than any of the other methods used, which included antiphlogistine, leeches, and omnopon. Associated with the relief of pain, the patient will feel more comfortable generally, and will tend to sleep better.

Therefore, when giving treatments, the technique should be that which will ensure the greatest relief of pain, with the least disturbance to the patient. No special attempt need be made to give the diseased lung the maximum amount of heat, as moderate currents are just as effective in relieving pain as currents as strong as the patient will stand, while a feeling of pleasant warmth is more restful than a feeling of heat so intense as to be almost burning.

### *Technique*

Any make of machine having sufficient power for the purpose in hand will be suitable. 500–800 watts is usually sufficient. The only essential is a switch on the primary current, so that the current may be switched off instantaneously when necessary. In order to ensure that this causes no shock, machines with an oscillator-resonator control should be used.

The leads must be well insulated, and not less than 4 ft. or more than 9 ft. long. 1 lb. lead is very suitable for the electrodes. Saline-soaked pads are contra-indicated, as they are messy if put on wet, and dangerous if used dry.

A terminal should be soldered on to the electrode, or fixed securely on in some other way. A lead slipping off would cause a very serious burn if considerable power were being applied. The size of the electrode will depend on the size and shape of the patient's chest, the area where pain is felt and the extent of the consolidation in the lungs.

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[1] C. A. Robinson, *British Journal of Radiology*, August, 1930.

7 in. by 5 in., or 8 in. by 6 in. is usually the best size for an adult. The two electrodes must be of equal size. They are placed flat on the opposite sides of the thorax. The best position is when they are placed antero-posteriorly, because, for reasons unknown, the results are not as good when they are placed on the lateral aspects of the thorax, even if the pain is mainly here. They may be placed in the midline, either with the long diameter horizontal or vertical, and in the latter case they may be misplaced slightly to one or other side of the midline.

The important thing is to get the electrodes opposite and, as far as possible, parallel to each other. As the thorax gets narrower towards the top, this is often difficult.

The simplest method of holding the electrodes in place is to let the patient's weight rest on the posterior one, while the anterior one is easily secured by a small piece of towelling on the top of it, and then stretching a long piece of flannel across that, the required tension being obtained by placing sandbags on the flannel, the sandbags resting on the bed between the patient's arms and chest.

Soaping the electrodes, or the skin, or both, is useful, and appears to keep the distribution of the current more even than if dry electrodes are used. Fischer diathermy soap is easy to apply on a small sponge, and forms a better intermediary between electrode and patient than ordinary shaving soap, as its conductivity is higher than most soaps.

It is absolutely essential that the electrodes should be warm when placed on the patient. The best way of ensuring this is to proceed as follows: The lead is attached to the electrode, which is then smeared with soap. It is then taken and passed two or three times through the flame of a spirit lamp, until it is at the desired temperature, as tested on the back of one's own hand. And this should be done at the bedside, and the electrode placed on the patient before it has time to cool. The posterior electrode is put in position first, and if the patient is being nursed sitting up, it is a simple matter to press the pillow back and slip it into position. If lying down, it is sometimes easier to get it behind by rolling the patient gently on to one side and letting him roll back on to it. A small towel placed behind the bed and the electrode keeps the latter in good contact with the patient's skin. Great gentleness is necessary. The anterior one should be ready at the same time and rapidly placed in position after the posterior one, or the latter will feel cold and uncomfortable. The electrodes being in position, and secured there, the current is switched on and slowly raised to a point where the patient feels a general and comfortable warmth in the region of the electrode.

It is unnecessary to push the current up until it feels uncomfortably hot. Often, after a time, the patient may feel that there is too much heat in one place. A little adjustment of the anterior electrode, or a little soaping of the skin under it, will often make the heated area feel more evenly warm.

The patient should be told to indicate by some simple movement, *e.g.*, raising his hand a little, if he feels it too hot. The patient must be carefully watched during the treatment, and the current switched off if it feels too hot, or if the patient gets a fit of violent coughing. In this latter case it is quite all right switching off the current on the primary main switch, and as soon as the coughing has ended switching on again straight to the maximum current value that was being used at the time.

The reading of the amperometer is of no great value, as it does not indicate the heat generated, unless the power input or resistance of the patient is also known. However, it gives one a rough idea of what the patient will take next time. The feeling of comfortable warmth for electrodes 8 in. by 6 in. may be felt anywhere between 0·8 and 3 amperes, depending on the position of the electrodes relative to each other, how they fit on the skin, and the condition of the skin surface, which will determine a good part of the resistance of the patient. Of course, the higher amperage will be tolerated when the most even distribution of current density occurs. It is not often possible to avoid some areas being hotter than others. The effect on the pain is often satisfactory, although it is obvious that the heating is somewhat uneven, say mainly at the upper edge of the anterior electrode. The duration of treatment should be about twenty minutes to half an hour, but events may intervene demanding stoppage of the treatment before this time. The patient may feel sleepy or unduly fatigued by the treatment. The treatment necessitates a slight amount of concentration, and this mental effort may fatigue the patient. If this is so, the current may be switched off at the end of a quarter of an hour.

When sufficient treatment has been given, the current is slowly reduced to zero value and then switched off. The electrodes are rapidly removed, and the soap gently wiped off the skin with a warm towel.

The treatment should be repeated in four hours' time. If the relief of pain is considerable and lasting, the interval between treatments may be prolonged to six or twelve hours.

On no account should the patient be roused from sleep for treatment. No other method of treatment being used at the time need be interfered with. Leeching can be done on the side of the thorax to avoid the region of the electrodes. Oxygen may be kept running, only do not let the spark gap of the machine be too close to the oxygen supply.

No benefit is likely to be obtained by continuing the treatment after the crisis or lysis has occurred.

Very delirious patients are best not treated, as diathermy does not control the excitability of the patient, and treatment is unsatisfactory with the patient moving about a great deal.

### *Conclusions*

Diathermy appears to be of real value in the symptomatic treatment of pneumonia. There is no evidence of a specific response to diathermy, and it is probable that the benefit obtained is not due to the heating of the lung. A technique to ensure gentleness in the treatment should be adopted.

### *Comments on the Use of Diathermy in Lobar Pneumonia*

It is unlikely that the diathermic current exercises any therapeutic action other than that of heat in the treatment of lobar pneumonia. Whether it elevates the temperature of the consolidated lobe of the lung is uncertain. It must not be forgotten that in pneumonia the temperature of the whole body is raised, and it is certain that the temperature of the affected lobe is already high before the diathermic treatment is commenced. The value of the treatment can rationally be attributed to the heating of the chest wall. The beneficial effect of a poultice is well known. By heating the chest wall throughout its thickness the diathermic current makes it play the part of a poultice which is in *actual contact* with the lung as well. It should not be forgotten that the temperature of an ordinary poultice begins to fall as soon as it is placed in position, whereas when the diathermic current is employed there is a continuous supply of heat throughout the duration of the séance.

The question of the effect of diathermic treatment on the rate of mortality is difficult to answer. In different epidemics the death rate differs within wide limits. For this reason it is difficult to assess the influence of diathermic treatment. Dr. Stewart's figures, obtained in the U.S. Marine Hospital (quoted above), certainly seem to show that diathermy is able to reduce the death rate.

There is little doubt that diathermy relieves the symptoms of the patient more efficiently than other agents. It also enables them to sleep.

## Bronchial Asthma

When diathermy is administered to the chest it can procure some degree of relief in some cases of bronchial asthma. Insufficient experience has been gained in order to assess the value of *local* diathermy—which can be administered to ambulatory patients—in comparison with *general* diathermy and the elevation of the temperature of the entire body to 103° F. or higher. The production of these high degrees of therapeutic fever necessitate the stay of the patient in a hospital or institute and the constant presence of a trained attendant during the treatment.[1]

The writer has had little experience in the treatment of bronchial asthma by *local* (thoracic) diathermy. Two cases were in hospital patients who had received a complete clinical and laboratory examination and medical treatment in the wards. After their discharge the patients were referred to the electrical department. Thoracic diathermy seemed to render them some relief. During the period while they were under treatment they said that their attacks were less severe and less frequent. A private patient derived considerable though temporary relief. His breathing always came easier during each application of diathermy and the relief lasted for two or three days.

Relief of much longer duration follows general diathermy with the production of therapeutic fever (see p. 355, in Section on Inductothermy).

### Other Diseases of the Lungs and Pleura

A few cases of other diseases of the lungs and pleura in which diathermy appeared to have exerted a favourable influence have been reported by various authors. Nagelschmidt has recommended the treatment in *early* cases of pulmonary tuberculosis, and has noted disappearance of fever and a gain of weight. Diathermy is inadvisable in later cases on account of the risk of hæmorrhage.

Saberton stated that he had experience in one or two cases of tuberculosis of the lungs associated with pleural effusion in which diathermic applications appeared to have hastened absorption of the fluid.

Kowarschik and other Austrian and German workers state that they have obtained good results in cases of chronic bronchitis, also in bronchial asthma.

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[1] A method of procuring therapeutic fever by means of the current from a diathermic machine is described on p. 158. The inductothermic method now is more generally employed. It is described in Section IV.

# CHAPTER XXII

# MEDICAL DIATHERMY IN OPHTHALMOLOGY

BY

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(*With an additional note on Iridocyclitis by* E. P. CUMBERBATCH.)

A NUMBER of pathological conditions of the eyes have been treated by medical diathermy. Of these, glaucoma, post-operative intra-ocular infections and orbital cellulitis have shown more convincing results than in the case of other diseases such as retro-bulbar neuritis, vitreous opacities, interstitial keratitis and chronic iridocyclitis in which improvement occurs in spite of any treatment, thus making it difficult to assess fairly the value of diathermy.

## Apparatus

The diathermic machine used at Moorfields Eye Hospital for medical diathermic work is illustrated in Fig. 88.

The electrodes are of lead. The small active electrode is circular and attached either to a rubber head band or to such a device as that designed by Law and described in the *British Journal of Ophthalmology*, XIX., p. 96, 1935 (see Fig. 89). The rubber head band must be carefully dried before use. The circular lead electrode is covered with wool soaked in normal saline. The surface of the wool must be smoothed out and applied neatly over the closed lids.

The indifferent electrode, also of lead, is covered with wool soaked in saline and applied to the forearm.

## Application of Current

The main current is switched on and the strength in the secondary circuit gradually increased by means of a tap of

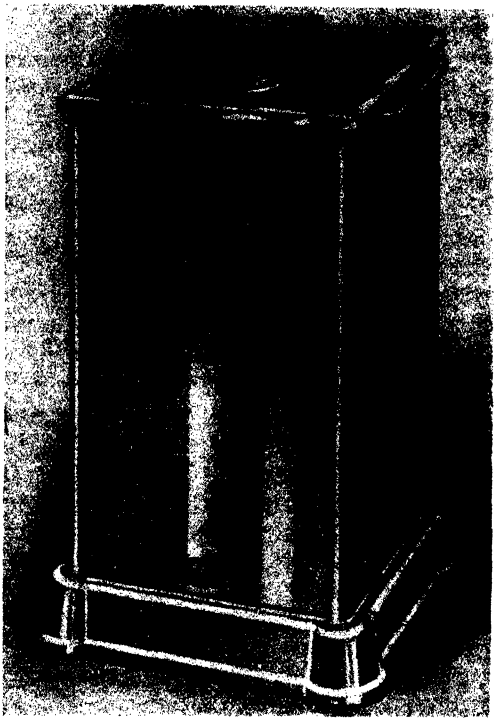
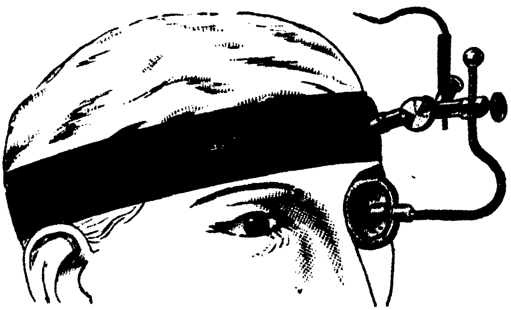


FIG. 88.—Diathermic Machine for use in Ophthalmology.



**89.—Head Band with Holder attached for maintaining Electrode in position on Eye.**

ance until a comfortable sensation of warmth in the region of the eye is experienced by the patient. The strength of the current varies with every patient on account of the differing resistance between the electrodes; the average amount tolerated is 300 to 600 milliamperes. After five minutes' treatment the current is gradually reduced until zero is reached on the milliamperemeter and then switched off and the electrodes disconnected. One treatment a day or on alternate days has been employed in the practice of the Moorfields electrotherapeutic department as a routine up to the time of writing this section.

### Therapeutic Field [1]

*Glaucoma.* In the treatment of acute or subacute glaucoma the results from diathermy are very pleasing. Pain is relieved at once and the tension reduced to a degree that renders operative measures relatively safe. Diathermy accelerates the action of eserine in its miotic effect. The relief of pain is quite remarkable. One patient who had suffered many hours of severe pain, insomnia and vomiting fell asleep during the diathermic treatment.

*Retro-bulbar neuritis* tends to recover to some extent satisfactorily in most cases in spite of any treatment. Law is of the opinion that diathermy renders this recovery more rapid and complete.

*Chronic iridocyclitis* receives treatment with atropine and other therapeutic agents so that it is difficult to assess the value of diathermy in conjunction with these other measures.

*Keratitis.* Law states that superficial punctate keratitis responds best to diathermy, but this treatment is irritating in some cases.

*Orbital cellulitis and post-operative intra-ocular infections* have in some instances responded well to diathermy.

The *neuralgic pain of herpes ophthalmicus* is said to be relieved, and Monbrun and Casteran claim that diathermy benefits corneal ulcers, especially those following facial paralysis.

My experience of diathermy in the treatment of *secondary*

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[1] For references to literature on "Diathermy in Ophthalmology," see p. 547.

*glaucoma* due to cyclitis, anterior uveitis, and keratitis with a deep anterior chamber, is that a number of such cases do not benefit by the treatment and are sometimes made worse.

Small *vitreous opacities and hæmorrhages* tend to be absorbed to a varying degree by natural processes. It is doubtful whether diathermy plays a part in accelerating this process. Some cases of large vitreous hæmorrhages are unaffected by it and useful vision is not restored to the patient.

(The use of diathermy in the treatment of detachment of the retina, new growths, cicatricial bands, trichiasis and intra-capsular cataract extraction is described in the Section on Surgical Diathermy (Chapter XLVI, p. 539).

### Additional Note on the Use of Diathermy in the Treatment of Iridocyclitis in Gonococcal Cases

Diathermy is of particular value in cases of iridocyclitis when a primary focus of gonococcal infection is present. In these cases the iridocyclitis is undoubtedly a metastatic inflammation. When parts like joints, fibrous tissues, etc., are secondarily affected the necessity for treatment of the primary focus of infection is realised. In cases of gonococcal iridocyclitis it is equally necessary to treat the primary focus, viz., the cervix uteri in women or the prostate and vesicles in men. When the pain is severe the treatment should be commenced by applying diathermy to the eye itself. Quick relief is obtained. The primary foci are then subjected to a course of diathermic treatment in the manner already described in Chapters XIII. and XIV.

In one of the writer's cases the iridocyclitis was subacute. It was present in a woman who was the subject of gonococcal arthritis. The application of diathermy to the eye quickly removed the pain. The treatment was completed by subjecting the cervix uteri to diathermy. (E. G., aged thirty-one ; treated in 1923.)

In another case the iridocyclitis was quiescent but the iris was adherent to the lens capsule. The patient complained of severe pain in his feet which he said had troubled him for about a year and had developed after an attack of gonorrhœa. His right eye had been very painful, but the pain had subsided before he came for treatment. Treatment was commenced by applying diathermy to his prostate and vesicles. The object of the treatment was not only to free the patient from pain but also to rid the prostate and vesicles from pathogenic infection in view of the proposed operation of iridectomy. At the end of two months the patient's general health was fully restored and he was able to walk three miles without difficulty. Iridectomy then was successfully performed by Mr. Foster Moore. No complications occurred. Four months later the patient came to report. He had maintained his health and freedom from pain and there had been no return of iridocyclitis. (Mr. V., aged thirty-five ; diathermic treatment in September and October, 1923 ; iridectomy in November, 1923 ; subsequent report in March, 1924.)

In a letter to the *British Medical Journal*, February 22, 1936, Mr. Everard Williams related a case of severe iridocyclitis in a woman of thirty-nine who was the subject of gross cervicitis. He subjected the cervix to *surgical* diathermy. The improvement was so rapid that she was able, while still an in-patient, to read a newspaper, whereas before the operation she had little more than the perception of light. The improvement was only temporary. The diathermic treatment was not repeated but a total hysterectomy was performed. Again the improvement was rapid and the patient was able to read while still in the ward. There was no relapse and she was able to resume her work as a needlewoman.

It will be noted that the diathermy administered to the above-mentioned case was *surgical.* When the cervix is subjected to surgical diathermy the mucous membrane of the canal is cauterised. This establishes a drainage of the glands but does not eradicate the infection completely. Non-surgical diathermic treatment administered in the manner described on p. 219 in the Chapter on Medical Diathermy in Gynæcology, though slower and more tedious, frees the cervix from pathogenic infection.

# CHAPTER XXIII

## MEDICAL DIATHERMY IN OTO-RHINO-LARYNGOLOGY

### Heating the Ear, Nose and Throat by the Diathermic Current

By placing plate electrodes in suitable positions on the face, behind the ears or on the neck it is possible to direct the diathermic current through various parts such as the mastoid process, the auditory organ and the Eustachian tube, the walls of the nasal chambers and the sinuses that lead into them, the walls of the naso-pharynx and oro-pharynx, and the larynx. There seems little doubt that a rise of temperature can be brought about in the less deeply situated bony and cartilaginous structures. In regard to the parts that have a deeper position, such as the walls of the naso-pharynx, sphenoidal and cavernous sinuses, etc., the question of the ability of the diathermic current to procure a rise of temperature must remain a matter of judgment. Nevertheless, it seems correct to conclude, on general principles, that some rise of temperature can be produced in the more deeply situated parts as well as the more superficial. It was shown in Experiment 15, p. 124, that the current could procure a rise of temperature in different parts of the buccal cavity, including the sublingual region, when the electrodes were placed externally, viz., on the cheeks. For this reason it may be assumed that a rise of temperature can likewise be obtained in the parts near the base of the skull if the electrodes are placed in higher situations on the cheeks, or behind the ears. This assumption may be made for the additional reason that a larger proportion of bony structures lie between the electrodes in their higher situation than is the case when they are placed lower down. Bone offers a high resistance and is not very vascular.

### Situation of the Electrodes

In order to gain information as to the parts which are included on the path of the current, when the electrodes are placed in different situations, it is helpful to examine the base of the skull and note the parts which are included when electrodes are placed in different positions on the exterior. The electrodes should be thin lead plates measuring 1 in. by 1·5 in.

In Fig. 90 the base of a skull is represented. Applied to the exterior are two electrodes. That on the *left* is situated over the mastoid region of the same side. That on the *right* is over the right maxillary antrum. When the electrodes are in this " antrum-mastoid " position the following parts are included between them ; on the *left* are the mastoid process, the organ of hearing and the Eustachian tube. On the *right* are the posterior and antero-lateral walls of the maxillary antrum. In the more central region are the lateral walls of the naso-pharynx, the walls of the sphenoidal and cavernous sinuses, the upper and posterior parts of the

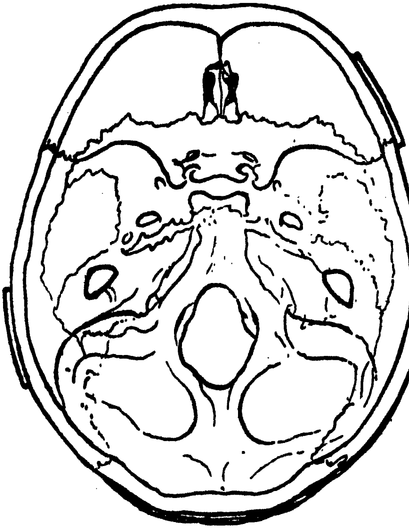

FIG. 90.—Base of skull to show regions included between two electrodes when one is behind left ear and the other on the right cheek. The letter A is opposite to the triangular areas indicating the tympanic cavities. (From Dan McKenzie's " Diathermy in Oto-Laryngology.")

walls of the nasal fossæ and those parts of the turbinate bones in that situation.

If the electrode over the *right* maxilla (see Fig. 90) is placed over the mastoid on the *same* side, the auditory organs of *both* sides will be included on the path of the current, but the nasal region and the pharyngeal ends of the Eustachian tubes will be excluded.

If the electrode over the *left* mastoid is placed over the antrum of the *same* side, the auditory organs will be excluded, but the posterior parts of the walls of both antra and the posterior parts of both nasal cavities will be included. To include the *anterior* walls of the maxillary antra in addition, the electrodes would have to be placed nearer to the middle line. In this position, however, there would be a concentration of current between the more closely related anterior edges of the electrodes and a risk of burning the skin. The risk can be overcome by connecting *both* electrodes to the *same* terminal of the diathermic machine. A third electrode is placed on the back of the neck and connected to the other terminal of the machine.

In regard to the oro-pharynx and larynx the electrodes may be applied to the sides of the neck. In this position, however, their anterior edges must not approach too closely to the middle line if the " edge-effect " is to be avoided. In the case of the larynx a single curved electrode may be applied so as to cover its anterior and antero-lateral aspect ; the other electrode being placed on the back of the neck.

## Electrodes

The electrodes are lead plates. Those which are applied to the mastoid or antrum should measure 1 in. by 1·5 in. A lint pad moistened with 10 per cent. salt solution is placed between the metal and the skin. The patient should be recumbent and the electrodes kept in position by rubber bandages. About four to five minutes should be occupied in increasing the current to a value of 0·5 ampere, which usually is the maximum the patient can tolerate without pain or aching. The duration of a séance is twenty to thirty minutes.

When one electrode is placed over the mastoid, and the other over the antrum of the opposite side, the organ of hearing on one side and the antrum on the other side receive the maximum share of the treatment. If at the end of twenty to thirty minutes the position of each electrode is reversed, and the current allowed to pass again for the same time, the remaining auditory organ and antrum will be treated. At the same time the more centrally situated parts will be treated for forty to sixty minutes. But as the current does not attain as high a density in these parts as in the antrum or auditory organ it may be concluded that the extra duration of the exposure compensates for the reduced current density.

Treatment in the way described is the most "inclusive," that is to say, it takes in the largest number of parts. Should it be desired, however, to subject the organ of hearing and the Eustachian tube of *one side only* to diathermy the electrode applied to the cheek on the opposite side might with advantage be made a little larger, say, 1·5 in. by 2 in.

Some workers apply an electrode directly over the auricle. If it is placed in this position it is not easy to ensure perfect contact. The writer uses an aural electrode constructed in two portions, one lying over the mastoid and the other just in front of the external auditory meatus. The two portions are connected by a stout semicircular wire.

### Diseases suitable for Diathermic Treatment

The pathological state which is most suitable for treatment by diathermy is inflammation—in cases where resolution by natural methods is unduly slow or incomplete. In *acute* cases diathermy is seldom administered. It might relieve symptoms but it is doubtful whether the normal rate of resolution would be accelerated. The presence of pus does not contra-indicate diathermic treatment provided there are channels allowing free drainage.

*Chronic Otitis Media.*[1] Diathermy is of service in the treatment of deafness and tinnitus caused by sero-mucous otitis media. If the inflammation is purulent at first the treatment should be given when the discharge ceases to be purulent, if catarrhal inflammation and deafness and tinnitus persist. When these symptoms are caused by other forms of middle-ear disease, diathermic treatment is not of much value in the major number of cases. Dan McKenzie described the results he had obtained in the treatment of 47 cases of deafness and tinnitus. Five cases were cured. Five were greatly improved. Some improvement was obtained in 13 cases. Of the remaining 24 cases, 22 showed no improvement, and in 2 the tinnitus was aggravated. Dan McKenzie concluded that diathermy had a more beneficial action upon deafness in cases where there was still some active inflammatory trouble or in cases where the inflammation had recently subsided and the effects were left. In regard to the effects of diathermy on tinnitus he concluded that in the milder forms of short duration, due either to simple catarrh of the Eustachian tube or to otitis media, the tinnitus and deafness disappeared together. In the continuous and intractable tinnitus of the established kind the results were much less satisfactory and also very variable.

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[1] In naming the diseases of the ear, nose and throat which may beneficially be treated by diathermy, and in describing the results that may be expected, the author is relying mainly on the experience of the late Dr. Dan McKenzie. Other English workers have written little on the subject, and the author's experience has been in the treatment of a haphazard collection of derelict cases derived from various sources. Those who are interested in diathermy in oto-rhino-laryngology should read Dan McKenzie's work on the subject ("Diathermy in Oto-Laryngology," published by Kegan Paul, Trench, Trubner & Co.).

*Diseases of the External Ear.* Dan McKenzie found diathermy of value in the treatment of chronic eczema of the auricle, especially in that variety in which the auricle and the wall of the meatus increase in thickness and swell to an extent that may cause obstruction of the meatus. A prolonged course of diathermy caused the swelling to disappear and the meatus to regain its patency.

The severe pain caused by furunculosis of the external auditory meatus is quickly relieved or even abolished by one or two applications of diathermy.

*Laryngitis.* Catarrhal laryngitis may advantageously be treated by diathermy after the acute stage has passed if symptoms of hoarseness and discomfort remain. Dan McKenzie stated that a prolonged course of diathermic treatment of the more chronic and obstinate forms of laryngitis, particularly the hyperplastic variety, might be tried because it had been found to benefit a somewhat similar fibrous hyperplasia of the auricle.

*Pharyngitis.* According to Dan McKenzie the form of pharyngitis in which diathermic treatment is of service is that in which there are tender points in the vicinity of the hyoid bone (probably caused by fibrositis). The patient complains of pain in the throat and base of the tongue but there are no signs of pharyngitis or tonsillitis.

*Rhinitis.* In acute rhinitis accompanying the common " cold " the symptoms can be relieved by diathermy. In simple chronic rhinitis, diathermic treatment leads, in time, to definite improvement, the catarrhal symptoms becoming moderated and the swelling of the turbinals diminished (Dan McKenzie).

## Note on the Use of Vacuum Electrodes in certain Diseases of the Nose

If a so-called vacuum electrode is in contact with a body surface which is not thoroughly moist, the current will not produce diathermy. Short fine sparks will pass between the glass and the surface. The sparks will heat the surface and produce *epithermy* rather than diathermy. At the same time they will stimulate the nerve endings and the glands. In addition they will produce ozone and oxides of nitrogen from the atmospheric gases. These new compounds may exercise a superficial germicidal effect. The use of this electrothermic method has already been outlined in Chapter I. and named *étincellage.* Further particulars are given in Section II. (p. 304 *et seq.*).

Treatment of certain diseases of the nose and throat by étincellage is practised by French workers and recommended by Leroux-Robert for eczema and painful fissure of the vestibule of the nose. In particular, it is recommended for *ozœna.* A special intra-nasal electrode provided with a speculum is required. All crusts are removed and the underlying tissue made as dry as possible. Sparks are directed for ten minutes over the floor and sides of the nasal cavity. Treatment is given daily and many séances are required. The secretion increases, the crusting is lessened and the mucosa tends to regain its normal colour. Leroux-Robert says that odour disappears, the results being better than those obtained by any other method.

The voltage of the ordinary diathermic machine is usually not high enough for producing the sparks used for étincellage. A suitably high voltage can be obtained from a machine fitted with a longer resonator. Or a separate resonator may be connected to the machine (see Section II., p. 304 *et seq.*).

## BIBLIOGRAPHICAL INDEX

"Diathermy in Oto-Laryngology." By DAN MCKENZIE, London: Kegan Paul, Trench, Trubner & Co. Ltd.

"La Haute Fréquence en Oto-Rhino-Laryngologie." By Dr. LEROUX-ROBERT, Paris: Masson & Cie.

# SECTION II

# EFFLUVATION AND ÉTINCELLAGE

## CHAPTER XXIV

## MEANING OF TERMS

French workers use the expression *effluvation* for a form of treatment in which an electric brush discharge—sometimes called an *effluve*—is directed on the body.[1] They use the word étincellage—which, literally, means sparking (étincelle being the French word for *spark*)—as the name for a form of treatment in which thin non-cauterising sparks are directed on the body. Both the effluve and the sparks are derived from a high-frequency current generator. English workers use the expression "high-frequency treatment" and include under this designation both effluvation and étincellage. As stated in the first chapter of the present volume it should be discarded and the qualification "high frequency" reserved as the family name for the currents employed in the different forms of electrothermic treatment. Effluvation and étincellage are *medical* (*i.e.*, non-surgical) forms of electrothermic treatment.

### The High-frequency Effluve and Principle on which it is Produced

The following description may enable the reader to understand what a high-frequency effluve really is, and it will serve to explain how the addition of an accessory part to a diathermic machine can enable the operator to procure a brush or sparks suitable for treatment by effluvation or étincellage.

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[1] If a considerable difference of electric potential is maintained between two conductors that are just too far apart to enable sparks to pass between them, a current nevertheless can pass across the air space. It passes, however, in the form of an electric brush. The brush is best seen when the positive conductor is spherical and the negative one is pointed. It is most distinct at the point. It broadens out towards the sphere. If the polarity of the conductors alternates with high frequency a brush can likewise be seen, and it is immaterial which conductor is pointed.

Imagine that a couple of wires are connected to the terminals of a diathermic machine (thereby bringing them in connection with the ends of the resonator). If the machine is set in operation and the free ends of the wires brought progressively closer together there will be a passage of sparks across the gap. The gap will have to be narrow because the diathermic machine is not designed to produce a high voltage. Much higher voltages are needed to produce sparks suitable for étincellage. Further, the sparks obtained by short-circuiting the resonator are far too thick and intense, and they would burn the skin—the diathermic machine being designed for the purpose of yielding a high *amperage*. Now if the resonator contained a great many more turns than the oscillator, or if a separate resonator of this kind were connected to the machine, it would yield a very much higher voltage and the sparks would be correspondingly *thinner*. Consequently, by employing a resonator of the kind mentioned and using special electrodes, it is possible to obtain sparks that are too thin to exert any cauterising action on the skin.

Imagine, now, that one of the wires above mentioned is connected to a metal sphere, the free end of the other being sharpened to a point. If the pointed end is brought near the sphere, but just beyond sparking distance, there will be a passage of current in the gap. It will take the form of a so-called "brush discharge." A brush discharge is faintly luminous and has a violet colour. It is most distinct at the pointed end of the wire. It broadens out as it approaches the other conductor, becoming less luminous or actually invisible in ordinary daylight. This brush discharge is also called an *effluve.*

## Nature of an Effluve

In an electric brush or effluve the electricity is conveyed by means of the molecules of the atmospheric gases. For this reason the name "convection current" is given to a brush or effluve. The oxygen and nitrogen molecules are ionised. Consequently they are set in motion under the influence of electromotive force. If the electromotive force is unidirectional there will be a stream of the ionised molecules in one direction only. If, however, the electromotive force periodically alternates its direction the ionised molecules will oscillate to and fro. In a high-frequency effluve the ionised molecules oscillate to and fro with the same frequency.

In an effluve, whether unidirectional or oscillatory, the ionised molecules are heated. This fact should be remembered because the biological effects brought about by an effluve are in all probability the consequence of the heat. The same is probably true in regard to the biological effects that follow étincellage. When the current passes in the form of sparks the molecules of the atmospheric gases are heated to a higher degree, as shown by the more distinct violet, or even the white, light which they emit.

### Reason why the Effluve or Sparks can bring about Biological Effects

When an effluve is directed on the skin the most obvious biological change is a cutaneous erythema. The erythema does not appear at once but it is not long in developing. This dilatation of the sub-epidermal vessels is probably a reflex action (perhaps an axon reflex). The afferent nerve endings in the skin are stimulated. The stimuli are different from those administered by electric currents such as the faradic, sinusoidal, etc. It is necessary to reach this conclusion because a current passing in the form of an effluve has so small a strength that it is negligible. The resistance on its path is enormous. It has to pass not only along the resonator—which presents a high impedance—but also along a lengthy air space between the electrode and the body. This air space offers a very high resistance. Further, the density of the current is greatly lowered by reason of the width and breadth of the air space. The power of the effluve to stimulate must be attributed to the heat of the ionised molecules of the atmospheric gases. The heat is delivered to the epidermis and received by the end organs of the afferent nerves.

When the effluve is directed on the skin it heats innumerable minute spots of the epidermis. These spots are ultramicroscopic or even molecular in area.

It is probable, also, that the stimuli delivered by *sparks* are thermic, rather than electrical, in nature. They heat less minute spots than the effluve and they heat them to a higher degree. On the other hand, it is likely that the spots which they heat are more discrete and less confluent than those heated by the effluve. When they are directed on the skin they produce an erythema which is more intense and more rapid in development than that brought about by the effluve.

The likelihood that the biological effects following the application of sparks or an effluve are due to the heating of the epidermis and its nerve endings is the reason for including effluvation and étincellage among the electrothermic methods of treatment.

### Other Biological Effects brought about by an Effluve and Sparks

Mention has already been made of the dilatation of the sub-epidermal vessels. It is possible, also, to procure contraction of voluntary muscle by means of an effluve. If a brush electrode like that described below (Fig. 92) is placed near a muscle, such as the deltoid, the effluve will procure a tetanic contraction which will persist while the electrode is in position. It is necessary to place the electrode fairly close to the skin, just beyond the distance at which sparks would pass. The contraction is not due to *direct* stimulation of the circumflex nerve or the muscle fibres. As already stated, a current in the form of an effluve is negligible in strength. The contraction is *reflexly* produced in consequence of the stimulation of the end organs of the afferent nerves that supply the skin of the shoulder.

Another biological effect which the effluve can bring about is rise of blood pressure. The rise can be demonstrated by a sphygmomanometer after the effluve has been directed over the back in sufficient strength to produce a marked erythema. Renton Elliot showed, by experiments on animals, that stimulation of the cutaneous nerve endings caused an increased output from the suprarenal glands, thereby causing a rise of blood pressure. It is possible that the rise of blood pressure in the human subject after effluvation is due to a similar action on the suprarenal glands.

It has long been known that stimulation of the skin of the loins can procure relief from amenorrhœa in young women whose pelvic organs are clinically normal. The stimulation can be brought about by means of an effluve from a static machine or a high-frequency resonator. It is possible that the endocrine functions of the ovaries are reflexly stimulated.

### Apparatus for Production of Effluve

In order to obtain an effluve or non-cauterising sparks for therapeutic purposes it is necessary to have a diathermic current generator and a separate resonator that contains a great many more turns than that from which the diathermic current is derived. A resonator of this kind—one of the so-called Oudin type—is illustrated in Fig. 91. It will be noted that the lowermost turns are more widely spaced than the remainder. They act as an

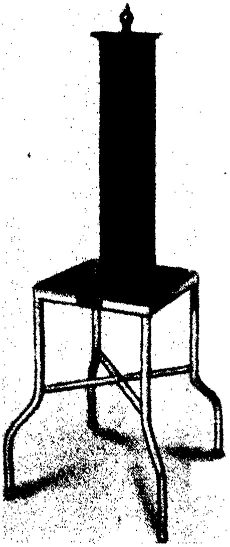

Fig. 91.—Oudin Resonator, mounted on a Trolley.

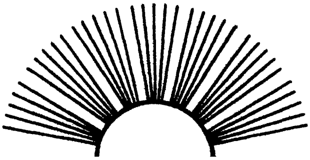

Fig. 92.—Diagram of "Hedgehog" Electrode used in Treatment by Effluve. (When used it is mounted on an ebonite handle.)

oscillator (in place of the oscillator fitted to the diathermic machine), and the remaining turns constitute the resonator. The diathermic machine must be fitted with special connections that will enable the lowermost turns of the resonator to be placed in the oscillating circuit. The machine by Stanley Cox (Fig. 57) is constructed for working in connection, when required, with an additional resonator for producing an effluve.

An electrode for use in treatment by the effluve is illustrated in Fig. 92. It terminates in a very large number of fine wire bristles which are mounted on a metal disc. It is sometimes called a " hedgehog " electrode. For use in treatment by non-cauterising sparks the so-called vacuum electrodes are employed. Electrodes of this kind are made in many different shapes and sizes. Some are illustrated in Fig. 73, p. 153.

### Administration of Treatment

For treatment by the effluve or sparks the electrode is connected to the free end of the resonator. The switch of the diathermic machine is opened. The operator then should test the effluve or sparks by bringing the electrode near to the palm of his hand. The length and intensity of the effluve can be varied by means of the coupling handle attached to the resonator. The handle should be moved upwards or downwards until the maximum length of spark or effluve is obtained. This procures the best resonance. The output of the diathermic machine may now be increased if longer sparks of effluve are required.

The patient should be in a sitting or recumbent posture, and the skin of the part to be treated should be uncovered.

### Therapeutic Uses

The effluve and non-cauterising sparks are directed on the skin for various purposes. One is to procure counter-irritation in cases of pain, particularly that due to neuritis. Another is to cause a rise of blood pressure in cases where it is unduly low (hypopiesia). The action of the sparks is more rapid, though less pleasant, than that of an effluve. When a vacuum electrode is rubbed over the skin the sparks stimulate the sebaceous glands. Their dried secretion collects on the glass of the electrode. In some cases of acne vulgaris and sycosis this form of treatment is of value. The ozone and oxides of nitrogen that are formed at the time of the passage of the sparks may exert a disinfecting action on the infected skin.

# SECTION III

# SHORT-WAVE TREATMENT

## CHAPTER XXV

## INTRODUCTION

It is familiarly known that electromagnetic (Hertzian) waves are emitted from circuits in which electric currents are oscillating. When the frequency of the oscillation is 1,000,000 cycles per second the waves have a length of 300 metres. Since the wavelength is inversely proportional to the frequency of the oscillation, it follows that when the frequency is 10,000,000 cycles per second the wavelength is 30 metres, and when the frequency is 50,000,000 cycles per second the wavelength is 6 metres. Waves of 30 metres or less are short in comparison with those of 300 metres.

Currents that oscillate with frequencies of 10,000,000 or more cycles per second and produce waves of 30 metres or less are employed in the so-called short-wave therapy. Originally, the body was placed in the path of the waves. Treatment by this method can rightly be called "wave treatment." This way of administering the treatment was found impractical. It was replaced by another method in which the body was included in the circuit of the oscillatory current that produced the waves. The name "wave treatment," however, was retained.

Short-wave treatment may consequently be defined as a therapeutic procedure in which the body is included in the circuit of a current that oscillates with a frequency high enough (10,000,000 or more cycles per second) to produce short waves (30 metres in length, or less).

It will be learnt shortly that the metal plates of the electrodes are not placed in actual contact with the body, but separated from it by some non-conducting material such as glass, ebonite or the air. The body, therefore, is in the field of a condenser. It will be remembered that the body can also be subjected to the action of a diathermic current (frequency of 2,000,000, or fewer, cycles per second) when it is in a condenser field. Consequently it is not the placing of the body in a condenser field, but the extra height of the frequency of the current that distinguishes the short-wave method from that in which the currents have a less high frequency.

### Historical Note

Although it had frequently been observed that the short Hertzian waves could produce heat at a distance from the transmitter, the first scientific investigation of the subject from a biological point of view was made by Gosset, Gutman and Lakhovsky. In 1924 they published a paper on the effects of very short waves on cancer in *plants*. The wave-length was about 2 metres, corresponding to a frequency of oscillation of 150,000,000 per second.

It seems that J. W. Schereschewsky, in the United States, was the first, in 1926, to publish a paper on the biological changes produced in *animals* by oscillations of much higher frequency than those employed in diathermic treatment. He also described the physiological effects which he had observed in consequence of the action of these currents, and in 1928 he published an account of their action on tissue cells and on sarcoma in mice. He was the first to employ the condenser field method. He did not utilise the waves themselves.

In regard to their *medical* investigation the priority belongs to Dr. Erwin Schliephake, of Jena, Germany. In the winter of 1926–27 he began to investigate the biological properties of short waves. At first he utilised the waves themselves but found that sufficient energy could not be obtained. Acting on the suggestion of A. Esau, professor of physics in the University of Jena, he adopted the condenser field method. Continuing his investigations on non-living conductors and animals he began to employ the method for therapeutic purposes, the first patient being treated in March, 1929. From that year onwards he treated various diseases and created a therapeutic field for the procedure still known as " short-wave " treatment.

## Nomenclature

It should be understood that the waves themselves are not utilised in the method practised by Schliephake or other medical workers. Strictly speaking, then, the expression "short-wave treatment" is inexact. It would be more precise when speaking of the method to state the frequency of the oscillation, rather than the length of the waves emitted. But as the waves themselves were originally used the expression "wave treatment" was not dropped. To-day its use seems to be universal for treatment in a condenser field by currents of much higher frequency than those used in diathermic treatment. These currents may be called "ultra-high-frequency currents" or "short-wave currents."

Other names have been suggested from time to time. The heat generated in the body by the currents of "ultra-high" frequency that produce "short" waves is called "neodiathermy" by Bordier, "parathermy" by Turrell, and "radiathermy" by Kobak and other United States workers. Some writers call it "short-wave diathermy."

## Long Waves and Short Waves

When we say that waves are *short* it means that they are short in relation to those that are produced when the frequency of the oscillation is less high. When the frequency is that of a diathermic current the waves are "*long*." Since the advent of "short-wave therapy" the name "long-wave therapy" has occasionally been used, though unnecessarily, for diathermic treatment. It will be convenient, therefore, to tabulate the waves in order of their length and add the corresponding frequencies of the oscillation.

| | Length of wave. | Frequency of oscillation. | |
|---|---|---|---|
| Long waves | 600 metres | 0·5 million per second | Treatment by diathermy. |
| | 300 ,, | 1·0 ,, ,, | |
| | 200 ,, | 1·5 ,, ,, | |
| Short waves | 30 ,, | 10 millions per second | Short-wave treatment. |
| | 15 ,, | 20 ,, ,, | |
| | 10 ,, | 30 ,, ,, | |
| | 6 ,, | 50 ,, ,, | |
| | 3 ,, | 100 ,, ,, | |

In short-wave treatment the frequency of the oscillation may be of any value between 10,000,000 and 100,000,000 per second (waves from 30 to 3 metres). It will be learnt below that the frequency of the oscillation is one of the factors determining the degree to which one conductor is heated in relation to another. Consequently it influences the distribution of the temperature in composite conductors. For these reasons it is necessary, for the purpose of description, to state either the frequency of the oscillation or, as is now the custom, the length of the wave. Since there is a considerable difference between 30 and 3 metres, Schliephake refers to those from 30 to 10 metres as " short," and to those that are shorter as " very short " or " ultra short." A classification of this kind is a matter of personal choice.

As for the dividing line between " high frequency " and " ultra-high frequency " and between " long waves " and " short waves " it may be said that it is indefinite. The transition of one into another is very gradual. It is generally agreed, however, that the frequency should be called " ultra high " when it is one of 10,000,000 or more cycles per second, and that the waves should be called " short " when they are 30 metres or less in length.

### Main Physical Effect of Currents that produce Short Waves

When a region of the body is included in a circuit in which high-frequency oscillation is taking place there is a production of heat in the tissues. Provided there is sufficient electrical energy a rise of temperature will occur, not only when the frequency is that of the diathermic current, but also when it has higher values—10, 30, 50 or more millions per second. Since the currents are thermogenetic in action their use in medicine constitutes one of the *electrothermic* methods of treatment. In other words, adopting the customary nomenclature, short-wave treatment is a form of electrothermic therapy. Whether the biological effects are due to any action, other than that of heat, will be discussed later.

## Heating a Conductor made of the Same Material throughout

When a simple conductor of this kind is placed on the path of a diathermic current it will be remembered that its superficial parts reach a higher temperature than the deep when the conductor is large in all three dimensions and the electrodes cover only a portion of its opposite aspects. In other words, the current is not restricted to the *direct* paths between the electrodes but spreads into the *outlying* paths as well. It is only when the thickness of the conductor is slight in proportion to the area of the electrodes that the current is restricted mainly to the parts that are directly included between the electrodes, thereby heating the deep parts almost to the same temperature as the superficial. The contrast between the distribution of the current, first, when the thickness of the conductor is considerable in relation to the area of the electrodes, and second, when the thickness is small in relation to their area, is represented schematically in Fig. 93, (*a*) and (*b*).

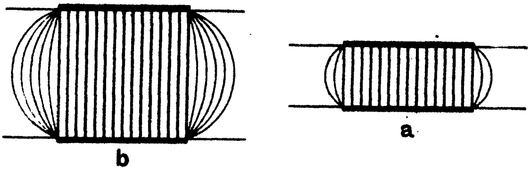

FIG. 93.—Diagram to represent greater Divergence of Lines of Current when Electrodes are far apart (*b*) than when they are close together (*a*).

A similar contrast would be observed if the frequency of the current were *much higher* than that of the diathermic current. But if the electrodes indicated in Fig. 93 (*b*) were placed, not in contact with the conductor, but at a distance from it, there would be more current in the conductor in the direct paths between the electrodes, and less in the outlying paths. Now when the frequency of the oscillation is not very high, the existence of a space of much width between the electrodes and the conductor would so greatly reduce the strength of the current that the conductor would be heated scarcely at all. Thus, if a diathermic current (frequency, say, 1,000,000 cycles per second) were used and the electrodes separated from the conductor by a space of ½ in., the current would be reduced to such a minute value that the conductor would be heated scarcely at all. But the interposition of a space of this thickness, or even a space as wide as 1 in., would not greatly reduce the strength of the current if the frequency of its oscillation were much higher than that of the diathermic current. The higher the frequency the greater can be the width of the space.

Experiments to show the possibility of restricting the heat generated by currents of the higher frequencies to the direct paths in broad conductors when the electrodes are at a distance from it were conducted by Schliephake. These experiments were made on simple conductors constructed of dough. He used large masses of the material. The condenser plates were smaller than the surfaces opposite which they were placed (without making contact). They were included in a circuit in which the oscillations were of much higher frequency than that of the diathermic current. It was found that the temperature rose as quickly in the *deep*, as in the superficial, parts.

In these experiments it was found that the heat was restricted almost wholly to the direct paths between the electrodes. In the outlying paths, just beyond the direct, there was scarcely any rise of temperature. The highest temperature was in the path joining the centres of the electrode. The temperature fell, but only slightly, as the lines joining the edges of the electrodes were approached.

It was found that if the electrodes were placed too close to the dough the superficial temperature rose to a higher value than the deep. The same thing happened if the electrodes were kept at the original distance but the length of the conductor increased. But if the electrodes then were placed farther away from the conductor an even distribution of temperature was again obtained.

The expression *relative dosage quotient* is used by J. Pätzold in order to state the degree of heat in the deepest parts of the conductor as compared with the degree in the superficial parts. Thus, if the deep and superficial parts are equally heated the relative dosage quotient is unity. On the other hand, if the deepest parts are heated only one-quarter of the degree to which the superficial parts are heated, the relative dosage quotient becomes 1/4. The influence on this quotient of the distance between the electrodes and the conductor was demonstrated also by Pätzold. The further the electrodes were moved away the closer was the approach of the quotient toward unity.

### Heating Different Conductors by the Same Frequency

When the frequency of the oscillation remains the same (in other words, when the length of the wave does not vary) it is found that different conductors are heated to different degrees. In the condenser field, provided that the field remains constant in strength, and the conductors are exposed for the same length of time, the differences in the degree of heating can be demonstrated by placing successively in the field artificial conductors, such as gelatin, modelling clay or dough, or dead tissue such as fat, muscle, or bone. The conductors must be as far as possible identical in size and shape.

The same conductor will always attain the same degree of heat if it is *homogeneous*, *i.e.*, made of the same material throughout. But the same kind of tissue taken from different sources will not necessarily reach the same temperature because its condition is likely to vary in the matter of moisture, proportion of ions present, details of histological structure, etc., according to its source. If the tissue of the same kind were *living* its condition would vary still more, even if it were derived from the same source.

### Heating the Same Conductor by Currents of Different Frequency

If the same amount of electrical energy is applied for the same time it is found that the same conductor is not heated to the same degree if the frequency of the oscillation is altered. There is an optimum frequency for each kind of homogeneous material. The optimum frequency for the same kind of tissue depends on its degree of moisture and the proportion of ions it contains—factors which vary according to the source from which the tissue is derived.

In living tissue there are other factors that decide the optimum frequency, such as the amount of blood and lymph it contains.

### Heating Composite Conductors

It has been mentioned elsewhere that a conductor composed of layers of different materials is not uniformly heated when it is placed on the path of a diathermic current. When the layers are *in series* the most resistant (impedant) one is heated to the highest degree. When they are *in parallel* the least resistant will be heated to a higher degree than the others.

Suppose, now, that a composite conductor of this kind is placed in a condenser field in a circuit in which the oscillation has a much higher frequency than that of the diathermic current. The layers will again be heated to different degrees but the distribution of the temperature will not be the same as that which a current of less high frequency would produce.

When the frequency of the oscillation is that of the diathermic current, the conductor behaves only as an ohmic resistance, and the distribution of the current is determined by the ohmic resistance of each layer. But when the frequency of the oscillation is much higher, an additional factor known as *capacitative resistance* comes into play. Suppose that a conductor is composed of layers of different material, each having a different degree of conductivity. A condenser, or capacity, will thus be formed. Its resistance, *i.e.*, its *capacitative* resistance will become lower as the frequency of the current grows higher. Assume now that a conductor contains both capacitative and non-capacitative resistances. If the current has a frequency not higher than that of a diathermic current the major proportion will pass along the non-capacitative resistance. On the other hand, a current of much higher frequency will pass, in greater proportion, along the capacitative resistance.

Some experiments were made by Koehler and Schliephake in order to show the different temperature distributions produced in a composite conductor by a diathermic current and another current that had a frequency of 20,000,000 cycles per second. The figures obtained and the materials of which the layers were made are indicated in Fig. 94. The temperatures obtained by a diathermic current are indicated below. The salt solution, which had the deepest situation and the best conductivity, was heated least of all. Above are shown the temperatures obtained by a current that oscillated with a frequency of 20,000,000 cycles per second. The salt solution was heated to the highest degree. The temperatures obtained by a current that oscillated with a still higher frequency, viz., 85,000,000 cycles per second, were as follows. The salt solution — 8·7° ; the fat — 7·8° ; the water — 6·8°.

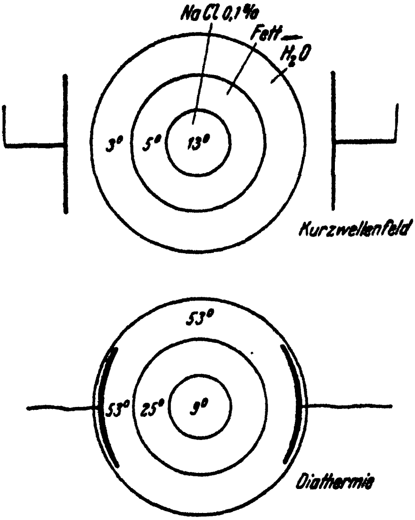

FIG. 94.—Distribution of Temperature in a Composite Conductor when the Frequency of the Oscillation is 20,000,000 cycles per second (upper part of figure), and when the Frequency has the less high value of an Ordinary Diathermic Current (lower part of figure). *Kurzwellenfeld = short-wave field. Fett = fat.* (From Schliephake's "Kurzwellentherapie"; first English translation by R. King Brown, M.D.: The Actinic Press Ltd.)

## The Body as a Conductor

The body is a conductor of extreme complexity. It is composed of different tissues of different resistance, some grouped in series, some in parallel and others both in series and in parallel. Below the skin is the fatty superficial fascia. Whatever its distribution in the deep parts may be, the current has to traverse a layer of subcutaneous fat. This tissue is heated to a higher degree than the underlying parts, whatever the frequency of the oscillation may be. The distribution in the underlying parts depends on the frequency of the oscillation. When the frequency is that of the diathermic current the body, like its component tissues, acts as an ohmic resistance. Where there are paths of different resistance the current will attain a higher density in those that offer a lower resistance. But when the frequency is much higher the distribution of the current will not be the same.

It has already been pointed out that a conductor made of layers of different conductivity offers a lower resistance (capacitative resistance) to currents of higher frequency. There are regions in the body where capacitative resistances of this kind exist, with adjacent non-capacitative resistances.

An organ with fat around it, like the kidney, constitutes a condenser. If it is the circuit of a current oscillating with the frequency of a diathermic current it may be assumed, theoretically, that most of the current will pass in the tissues around the organ that have a lower resistance than fat. On the other hand, a current of much higher frequency would find the capacitative resistance of the kidney and the peri-renal fat lower than that of the adjacent tissues. Theoretically, then, there will be more likelihood of the renal tissue being heated by currents of higher frequency than the diathermic current.

Red blood corpuscles act as minute condensers because their cell walls are poorer conductors than the material they enclose. As they are suspended in a good conducting fluid (the serum) the blood is very suitable for a study of the relative distribution of currents of different frequency in the corpuscles themselves and in the serum. When the frequency is that of the diathermic current the greater proportion of the current passes in the serum ; the capacity resistance of the corpuscles is too great. When the frequency begins to be "ultra-high," more of the current passes through the corpuscles because the capacity resistance begins to fall.

If an organ like the liver is in the circuit of an oscillatory current the cells act as a number of minute condensers. The current can pass both in the inter-cellular spaces and through the cells themselves. A current of less high frequency will pass in greater proportion *between* the cells, while one which oscillates with a much higher frequency will pass in greater proportion *through* the cells.

There is some experimental evidence in favour of this conclusion. Philippson[1] experimented with a portion of the bloodless liver of a rabbit and found a resistance of 1,950 ohms for a current oscillating with a frequency of 500 cycles per second. With a frequency of 50,000 the resistance was 1,025 ohms. With a frequency of 5,000,000 the resistance was as low as 245 ohms. Since there are many more paths through, than between, the cells, the low resistance found for the current of very high frequency shows that currents of very high frequency pass through, rather than between, the cells.

### Experiments on the Cadaver

Portions of the lower limbs which had been amputated were subjected to the action of the diathermic current and the temperatures compared with those obtained in the condenser field. In the condenser field it was found that the highest temperature was that obtained in the subcutaneous fatty tissue. In the interior of the bone it rose to about half the value obtained in the fatty tissue. The same leg was afterwards subjected to the action of the diathermic current. The temperature in the subcutaneous fat quickly rose to a much higher temperature than that obtained in the first experiment, whereas that of the bone rose only slowly and ultimately attained a rather lower value than in the first experiment.

### Experiments on Living Animals

Conclusions as to the distribution of oscillatory currents in living objects are difficult to make because thermometric findings are influenced by the heat-convecting action of the blood. Experiments on the leg of a living dog have shown a higher rise of temperature in the subcutaneous fat than in the muscles or bone when the frequency was that of the diathermic current. The reverse was the case when the limb was heated in a condenser field and the frequency of the oscillation much higher.

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[1] Académie Royale de Belgique: *Bulletins de la Classe des sciences:* Séance du 4 Juin, 1921.

### Relative Value of Ultra-high-frequency Currents for Heating

For physical reasons it would appear that the body could be heated to a greater depth by means of ultra-high-frequency currents than by those of the frequencies employed in the practice of diathermotherapy—provided the body is placed in a condenser field with the electrodes at a suitable distance from it. It would appear also that regions of the body that are comparatively inaccessible to the thermogenetic action of the diathermic current could be heated by currents of much higher frequency. Experiments on non-living conductors, the cadaver and living animals appear to show the superiority of ultra-high-frequency currents (short-wave currents) for thermogenetic purposes. Before this conclusion can be accepted it will be necessary to consider some observations that have been made on the intact living human body.

### Heating the Living Human Subject

Schliephake conducted experiments on the living human body in order to ascertain the temperature that might be produced in the interior of the trunk, first by means of the diathermic current and afterwards by the short-wave method.

In one experiment a thin rubber tube containing a thermocouple was introduced, by way of the œsophagus, into the stomach. Plate electrodes measuring 9 cm. by 12 cm. were placed on the abdomen and back. A diathermic current was used and increased to the limit of toleration. The temperature in the stomach rose by 0·9° C. On another occasion the condenser field method was utilised. The temperature rose by 1·6° C. In both experiments the duration of the exposure to the heating action was the same, viz., 1·5 minutes.

In the two following experiments the thermocouple was introduced into the pelvis of a kidney in a catheter by way of the ureter. In the first of these experiments a diathermic current was used, and in the second the renal region of the trunk was in a condenser field. In both experiments the electrodes measured 9 cm. by 12 cm., and the length of exposure to the electrothermic heating was nine minutes. The temperature rose 0·53° C. when the diathermic current was used, and 1·2° C. when the condenser method was employed.

In two more experiments the thermocouple was placed in a tube and passed into the œsophagus. The electrodes were applied over the sternum and the middle of the back. After three minutes the diathermic current procured a rise of 0·4° C.; whereas in the condenser field the rise was 1·3° C.

The experiments briefly described above may prove to be of high importance. If the findings can be confirmed by independent workers they will have a far-reaching influence on electrothermic treatment. But one important question must be asked. Was the thermocouple in position while the current was passing ? If so, the rises of temperature might have been due to a local heating of the tissue around the metal of the thermocouple by eddy currents. It is not stated by Schliephake whether the thermocouple was removed before the current was passed and again introduced after the current was stopped. The same question must be asked in regard to all the other experiments in which thermocouples were used.

The writer was unable, by means of a diathermic current, to demonstrate any rise of temperature in the renal region (see p. 123). In Schliephake's book there is no account of any experiments in which the pelvis is placed in a condenser field and subjected to the action of ultra-high-frequency currents (short waves). It is quite easy to introduce thermometric instruments into the interior of the pelvic cavity. The difficulty of procuring more than a minute rise of temperature in the pelvic cavity when a *diathermic* current is used and both electrodes are outside has been shown by the experiments described in Chapter VII. The writer has performed similar experiments, using currents of much higher frequencies (10,000,000 to 50,000,000 cycles per second—wavelengths from 30 to 6 metres), and placing the pelvis in a condenser field, but was unable to demonstrate any rise of temperature in the posterior fornix vaginæ. The probable reason for the failure to obtain a rise of temperature is the high vascularity of the pelvic organs and the rapid convection of heat away by the blood stream.[1]

### How Ultra-high-frequency (Short-Wave) Currents bring about Biological Effects

The physiological and therapeutic changes that these currents can produce can rationally be attributed to the action of *heat*. Some workers believe that these changes cannot wholly be explained as the consequence of heat alone because certain effects can be brought about without an apparent rise of temperature, or a rise sufficient to explain them. Bordier originally showed that fish in a bowl of water placed in a condenser field and exposed to the action of ultra-high-frequency currents were killed in spite of the fact that the water did not attain a lethal temperature. This experiment does not prove any specific action on the part of the current because the temperature of the fish themselves was not taken. Probably it would have been found to be lethal in degree. A thermometer can only measure the temperature of a fluid object as a whole, or of macroscopic portions of a solid object. If a medium contains microscopic particles that can act as condensers, a current of very high frequency can heat them without raising the temperature of the medium as a whole. The medium can, in fact, be exposed to a draught of ice-cold air.

Sir Leonard Hill and H. J. Taylor placed an excised frog's heart in Ringer's solution in a quartz vessel and exposed them to the action of waves which were 3·4 metres in length. The behaviour of the heart was precisely the same as that which is known by physiologists to occur when a frog's heart is place in Ringer's solution at different temperatures. (*The Lancet*, February 8th, 1936.)

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[1] Other workers, however, have been able to obtain slight rises of temperature (from 1° to 2° F.). Some employed benzine thermometers. The subjects of some of the experiments felt that the entire body was becoming hot. Before concluding that the current is able to generate heat locally in the pelvic organs, it is essential to measure the *general* temperature. This precaution is necessary because the rise of temperature within the pelvis may be part of a general rise due to convection of heat from the pelvic wall.

## Generators for Use in Short-wave Therapy

Machines which generate currents of the extremely high frequency used in short-wave treatment are constructed on the same principle as diathermic machines. They are provided, however, with an additional device for the purpose of obtaining the maximum current in the resonating circuit (the circuit in which the patient is placed) in relation to the current in the oscillating circuit. It has already been mentioned that in order to bring this about it is necessary that the capacity of the condenser in the oscillating circuit (K) and the amount of self-induction (L) in the same circuit should bear a definite relation to the capacity (K′) and the amount of self-induction (L′) in the resonating circuit. $K \times L$ should be equal to $K' \times L'$. When administering diathermy it is not essential for KL always to be equal to K′L′. But when short-wave treatment is given there is considerable loss of energy in the transformation. It is necessary, therefore, to have an adjustable condenser or inductance in order to allow for the different capacities of various patients or of the regions that are included in the resonating circuit.

The generators are either of the *spark gap* type or the *valve* type. The former are suitable only when small regions of the body are to be treated. Machines of the valve type are more often used.

Below are given some particulars of the two valve type machines, of which the writer has had the largest experience.

### 1. The "Megatherm"

(*Electro-Medical Supplies*)

This machine is illustrated in Fig. 95. Two of the side panels have been removed in order to display its interior.

In the upper compartment are seen two triode valves. When a small switch is opened a current (derived from the A.C. main by way of a suitable transformer) passes along the filaments of the valves and heats them to redness. As is the case with other generators of the valve type the amount of electrical energy taken by the machine depends

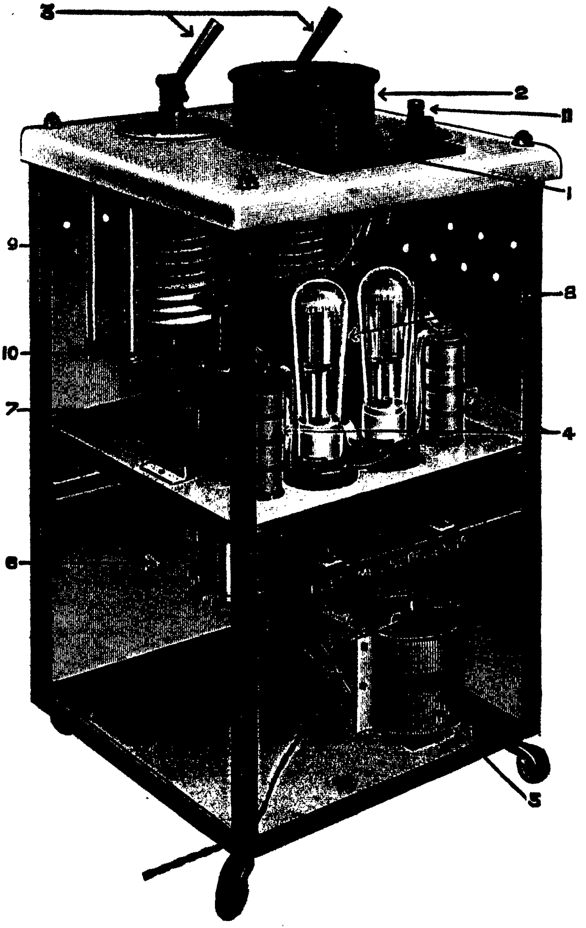

Fig. 95.—The "Megatherm" Ultra-High-Frequency Current Generator for Use in Short-Wave Treatment. (Electro-Medical Supplies Ltd.)

on the degree to which the valve filaments are heated. It is necessary, therefore, to have a device for regulating the current that heats the filaments. In the machine illustrated it is a variable resistance. It can be seen in the lower compartment in front. By turning a disc on the control panel (partly visible behind the right-hand terminal), as much or as little of the resistance can be placed in the path of the current that supplies the filaments. When the disc is rotated, a pointer moves from " weak " to " medium " and then to " strong." It enables corresponding amounts of current to pass along the filaments, as well as any intermediate amount.

When the patient is connected to the output terminals (seen on the control panel in front) the disc that controls the current to the valve filaments is rotated so that the pointer is opposite " medium." Alternating current from the main passes through the primary winding of the static transformer (which can be seen in part in the lower compartment). A current now oscillates with ultra-high-frequency in a circuit containing the valves, an inductance and a condenser. The frequency is " ultra high " because the inductance contains only a very few widely spaced turns and the condenser is one of small capacity. The actual height of the frequency (and therefore the length of the waves) can be varied by regulating the capacity of another condenser which can be seen in the upper compartment behind, on the left side. The regulation is effected by rotating one of the " tuning " handles seen on the control panel behind. When this handle is rotated a pointer moves over a scale marked with lines and figures from 6 to 30. If the pointer is, say, at 6, the current in the oscillating circuit has a frequency of 50,000,000 cycles corresponding to a wavelength of 6 metres.

The patient is in a separate (resonating) circuit. For the purpose of securing maximum resonance a variable condenser is placed in this circuit. It can be seen by the side of the variable condenser in the oscillating circuit, and its regulating handle is partly visible on the control panel.

When treatment is to be given the first variable condenser is adjusted so as to obtain the frequency and wavelength

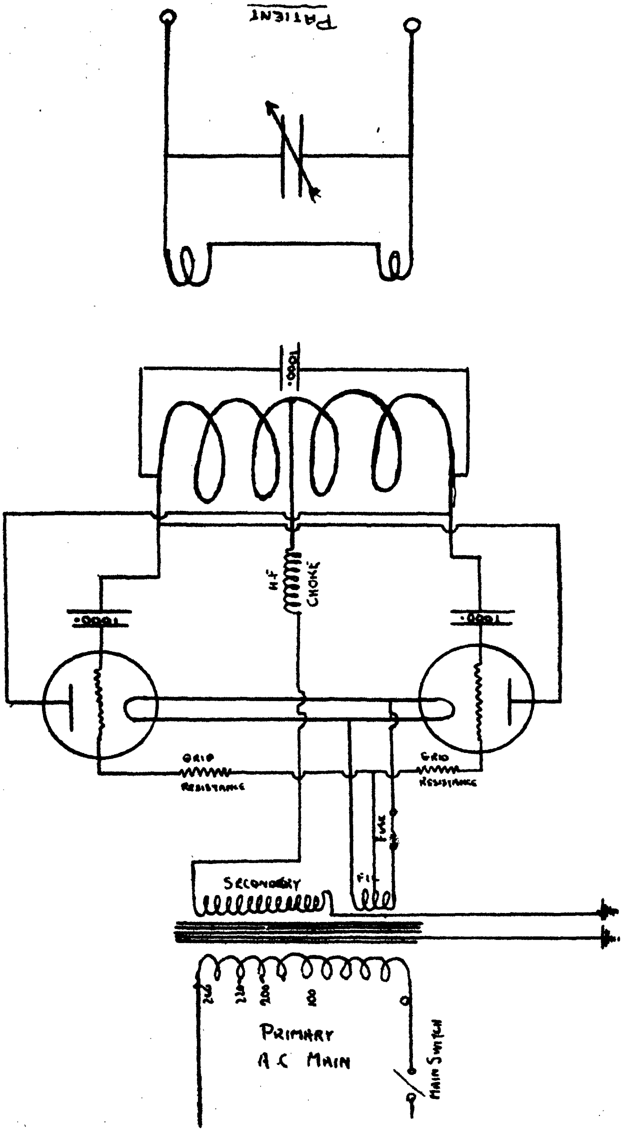

FIG. 96.—Plan of the "Megatherm" Generator.

desired. The disc that regulates the valve filament current is placed with the pointer at *medium* and then the second variable condenser is adjusted until the maximum resonance is obtained. While the second condenser is being adjusted the needle of the energy meter (seen on the centre of the control panel) moves over its scale. It reaches a certain distance and then it begins to move backwards. When it has reached its maximum distance the maximum resonance has been obtained. The distance it reaches is a measure of the energy received by the machine. There is no practical way of measuring the strength of the current in the patient's circuit. When it is desired to increase or diminish the current in the patient's circuit the disc that controls the valve filament current is rotated forwards or backwards, and the second condenser is adjusted to procure the maximum resonance.

A plan of the " Megatherm " is shown in Fig. 96.

### 2. The Universal Radiotherm

(*Siemens*)

This machine is illustrated in Fig. 97. It contains a single valve. It is constructed to yield either 6-metre or 30-metre waves (currents of 50,000,000 or 10,000,000 cycles per second). At the back of the control panel are seen two scales, each with a needle that can move over it. The needle on the left indicates the intensity of the filament current. When the patient is connected, the current he receives is regulated in the manner already described. The intensity of the current passing in the valve filament is adjusted by a control disc and indicated by the position of the needle on the scale at the back of the control panel (left side). To obtain maximum resonance another disc is turned until the needle moves as far as possible over the other scale shown at the back of the control panel.

The Siemens firm also construct a smaller machine of the valve type which yields 6-metre wave currents alone. They also construct a machine which produces waves less than 6 metres in length. It is very massive in size and costs over £700.

The Electricitäts-Gesellschaft "Sanitas," of Berlin, specialise in the manufacture of short-wave apparatus of the spark gap type. Good machines of the valve type are now obtainable from English manufacturers. In addition to that already described there are others by Stanley Cox, and by Watson & Sons.

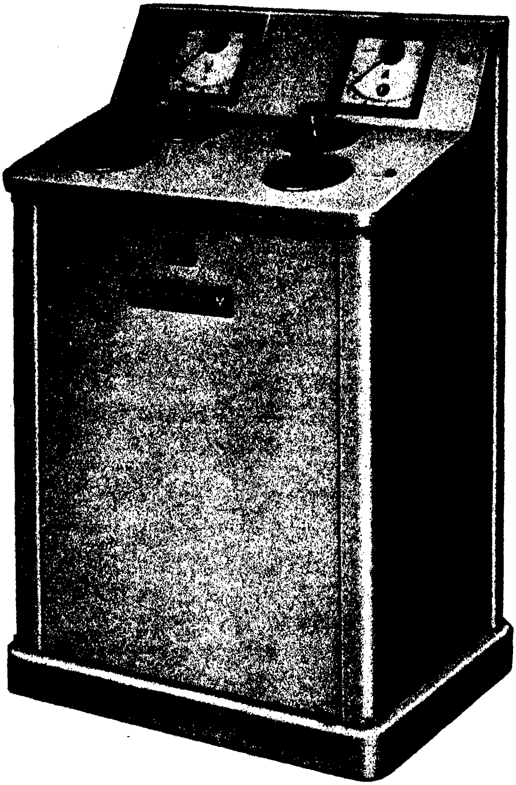

FIG. 97.—The "Radiotherm" (Universal) Machine. (Siemens.)

## Electrodes

The electrodes that are applied to the exterior of the body are metal plates completely enclosed in some pliable non-conducting material. They are not placed in direct contact with the skin, but are separated from it by one, two or three layers of perforated black felt. The thickness of each layer is ¼ in. Generally speaking, the deeper the situation of the part requiring treatment the greater must be the total thickness of the felt layers.

Schliephake advises the use of the so-called "shoe electrodes." One is illustrated in Fig. 98. They are made in various sizes. The electrode proper is a metal disc mounted inside a circular tray made of Schott's laboratory glass. An ebonite disc covers the open end of the tray. The bottom of the tray is placed in contact with the skin. The metal disc can be brought close to the skin or moved farther away by adjusting a screw handle mounted on the ebonite covering. A shoe-electrode of this kind is placed on one aspect of the part to be treated and a similar one is placed on the opposite aspect. They are kept in position by rubber bandages.

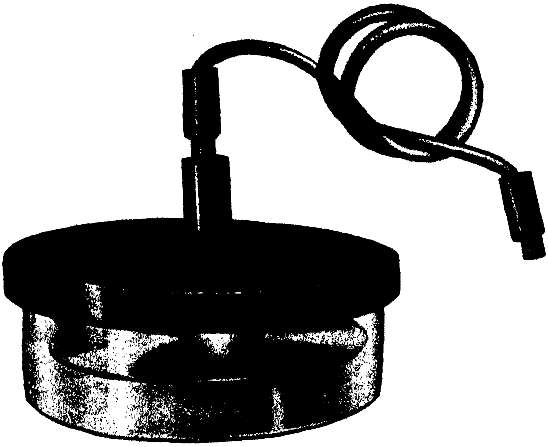

FIG. 98.—" Shoe-Electrode."

## Choice of Wavelength in Treatment

If the electrical conductivity and dielectric capacity of each kind of tissue in different pathological states were known, and if they remained constant for each pathological state, it would be possible to prescribe the wavelength that would procure selective heating. This, unfortunately, is not the case. If it were possible to procure selective heating of the tissues desired the distribution of the temperature would soon be disturbed on account of the spread of heat by conduction and convection. In actual therapeutic practice one employs wavelengths of about 6 metres when the part requiring treatment is relatively small, using the longer waves, *e.g.*, those of 30 metres, when large regions, such as the chest, are to be treated. Small regions can be treated with the longer waves, but the use of the shorter waves for large regions is wasteful and insufficient energy is obtained. Waves as short as 5, 4 or 3 metres would seem more suitable for treatment of disease in bone.

### Advantages and Disadvantages of the Use of Ultra-high-frequency Currents (Short-wave Currents) for Heating the Body

Apart from the possibility of procuring deeper heating, or selective heating, the employment of electrodes of the kinds above described has the advantage of simplicity. When the ordinary diathermic current is used it is necessary to lather the skin or prepare saline pads ; in addition, it is difficult to prepare electrodes that will make even apposition with regions that have irregular surfaces, such as the face. On the other hand, the metal of the electrodes used in short-wave treatment does not make contact with the skin, nor has the skin to be prepared. It is not necessary to remove thin covering clothing provided it is dry and contains no metal. When " shoe-electrodes " are used they can be supported in position on a stand designed for the purpose. The rubber bandages can then be discarded. When this supporting stand is used the electrodes need exert no pressure on the skin. This is obviously a great advantage when the part to be treated is very tender on pressure.

The main disadvantage associated with treatment by short-wave currents is the inability to measure the current in the patient's circuit. Dosage, therefore, has to remain a matter of the operator's judgment. In the early days of short-wave treatment the subcutaneous fat was sometimes overheated. The patients were unaware of any sensation beyond a mild degree of warmth at the time. During the course of the next twenty-four hours the skin reddened and developed the appearance of a burn. Misadventures of this kind were caused because the metal of the electrode was too close to the skin. They can be avoided by placing the metal at a sufficient distance from the body.

### Therapeutic Field and Results of Short-wave Treatment

The longest experience in the treatment of disease by short waves has been obtained by Schliephake. Commencing in 1929 it has extended over a period of seven years. He has created a therapeutic field for this form of treatment. The diseases which he has successfully treated are those due to local pyogenic infection of the skin (furuncles, carbuncles, whitlows), of the nail bed (paronychia), of the tooth sockets (paradentosis), and bone (osteomyelitis). He has treated several cases of intrathoracic suppuration (empyema, pulmonary abscess, suppurating pneumonia). Judging by the clinical accounts illustrated by skiagrams, the results were excellent and cures were apparent. In angina pectoris he often obtained relief. Relief was also obtained in some cases of bronchiectasis and early pulmonary tuberculosis. He has obtained success in the treatment of empyema of the nasal sinuses, and he maintains that the effect of short-wave treatment in cases of catarrh of the upper air passages is unique. He has treated numerous cases of the common "cold," and in most of them the catarrh disappeared the day after the treatment. Relief was obtained in chronic cases of laryngitis and tonsillitis. In arthritis the results varied. In cases of inflammation of the sweat glands of the axilla the effect of the treatment was to abort the inflammation, or, if suppuration had commenced, to hasten the evacuation and the subsequent cure.

The findings of Schliephake that seem to be the most noteworthy are those that concern intrathoracic suppuration. The writer has had no experience in the treatment of pathological conditions of this kind. Those who are interested in the subject should study Schliephake's book on short-wave treatment. There is a good English translation of the second German edition, published by The Actinic Press Ltd.

In the treatment of a number of the other diseases included in the field for treatment by short waves the results obtained by the writer are similar to those of Schliephake, more especially in cases of furuncle, carbuncle, whitlow, paronychia and inflamed glands. In the earlier days of diathermotherapy it was thought that *acute* inflammation, especially if pus were present or suspected, should *not* be treated by diathermy. The same *veto* was not placed on short-wave treatment. Having treated many cases of *acute* inflammation by diathermy with success and without disaster, the writer determined, when obtaining experience with the short-wave method, to treat different diseases by both methods, subjecting some cases of each disease to diathermy and the others to short-wave treatment. Below is given a brief account of the findings.

*Carbuncle.* Forty-six cases were treated, 31 by the short-wave method and 15 by diathermy. They were present in regions such as the neck, forearm, axilla, thumb, finger, wrist, temple, submaxilla, shoulder and leg. A few had been incised but they were afterwards sent for electrothermic treatment because the pain persisted. With three exceptions, the cases responded rapidly, *both to diathermy and to short-wave treatment.* Pain was lessened after the first treatment and completely abolished after the second or third. Discharge became profuse after the second or third treatment and sloughs afterwards began to separate. Both forms of treatment were given daily for five or six days and on alternate days during the second week. In the short-wave method the wavelength was 6 metres.

No difference whatever was detected in the results obtained by diathermy as compared with those obtained by short waves. Treatment by the last-mentioned method, however, has one advantage : the electrodes need not make contact, or firm contact, with the painful swelling. Consequently it is better tolerated by the patient.

The cases which did not respond so rapidly were the following. The *first* was that of a carbuncle of the neck in a man of forty-six. Seven daily treatments with short waves failed to relieve the pain; the sloughs had not separated. Diathermic treatment was then instituted, five applications being given in five days. The sloughs separated at the end of this time. The patient said that diathermy afforded more relief than the short-wave treatment. In the *second* case the carbuncle was on the neck of a boy aged five. After the third short-wave treatment his temperature rose to 101° F. and his pulse rate increased to 140. As he did not appear to be unduly ill the treatment was continued. Discharge and sloughing commenced; the temperature and pulse rate fell, and in ten days there was a healthy granulating surface. The *third* case was that of a carbuncle of the neck in a man of fifty. It had been incised and inflammation afterwards spread to adjoining parts. Pain and inflammation were quickly lessened by short-wave treatment. While the treatment was being given another carbuncle appeared on the thigh. It was subjected to short-wave treatment. At first it increased in size but did not suppurate. Twenty days later it had disappeared.

*Furuncle.* Eighteen cases were treated, 11 by short waves (6 metres) and 7 by diathermy. In 1 of these cases (in a man of thirty-seven) both diathermy and short waves procured only a trifling degree of relief. In another (in a boy of eleven) the furuncles were scattered on the left leg. Some were treated by short waves and others by infra-red rays. Both forms of treatment were equally successful. In a third case (in a male of thirty-five) of two years' duration some relief was procured by short-wave treatment. General ultra-violet ray treatment was more successful. In the remaining 15 cases both diathermy and short-wave treatment brought about a rapid disappearance of pain and swelling, and cures were soon obtained. Here, again, short-wave treatment was no more rapid than diathermic treatment.

One of the cases was that of a furuncle in the vestibule of the nose of a boy aged seven. Short waves quickly procured relief of pain. After a week there was no trace of the furuncle. By reason of their inaccessibility to diathermic treatment, furuncles in this situation are specially suitable for the short-wave method. The same is true of furuncles in the external auditory meatus. A private case of this kind, not included in the number referred to above, had been treated by incision under general anæsthesia, but derived little relief of pain. Relief quickly followed the first short-wave treatment, and after the third, all symptoms and signs had disappeared.

*Lymphadenitis.* Seven cases were treated. In the *first*, in a male of seventeen, there was a discharging gland in the neck ; the patient was tuberculous. Short-wave treatment procured relief but healing did not occur. Diathermic treatment was afterwards given but without success. In the *second* (male, aged four) the gland in the neck had previously been incised but a persistent discharge remained. Short-wave treatment reduced the swelling and lessened the discharge. As healing was delayed, diathermic treatment was commenced. Healing eventually occurred but the process was very slow. In the *third* case a painful swollen gland in the neck had been incised but no pus was found. Short-wave treatment was commenced. The temperature rose and a discharge of pus commenced. After being profuse for a few days it came to an end and healing soon occurred. In the *fourth* case (female, aged thirty-five) there was a painful enlarged gland in the axilla. The overlying skin was not inflamed. After the third application of short waves the general temperature rose. The surgeon made an incision and evacuated pus. The swelling and discharge soon disappeared under further short-wave treatment. In the *fifth* case (female, aged twenty-seven) there was an enlarged painful suppurating gland in the submaxillary region. After the second short-wave treatment the discharge increased and the pain disappeared. The treatment of this case could not be continued because the patient was unable to remain in London. In the *sixth* case (male, aged forty-five) there was an enlarged painful gland in the axilla. It was treated by *diathermy*. The pain was relieved. As the gland began to soften, an incision was made and pus was removed. Healing eventually occurred after the diathermic treatment was continued. The *seventh* case (male, aged fifty-six) was also treated by *diathermy.* There was a chronic discharging inflammatory swelling adjacent to the left elbow. It had refused to yield to the ordinary forms of treatment. The improvement was slow but progressive under diathermic treatment. Healing was complete in twenty-three days.

These cases, though small in number, seem to show that there is little to choose between diathermic and short-wave treatment.

*Paronychia.* This responds rapidly and successfully, as a rule, to short-wave treatment. In 2 cases a trial was made of *diathermic* treatment. In one (male, aged forty-nine) there was a painful septic inflammation of the thumb, and the nail was loose. After the seventh diathermic treatment the inflammation had gone and a new nail had commenced to grow. In the other case (male, aged thirty-seven) there was suppuration of the hallux and the nail was loose. After diathermic treatment during a course of twenty-four days the toe was healthy in appearance and a new nail had commenced to grow.

*Whitlow.* In the treatment of this disease there appears to be no difference in the results of diathermy and those of short-wave treatment.

*Indolent Septic Wounds and Ulcers.* Nine cases were treated. The *first* was in a male of thirty-seven who had received a scalp wound. It had afterwards been infected and refused to heal under ordinary methods of treatment. Short waves gave immediate relief of pain and caused the discharge to increase. After eight days the discharge ceased and the wound was nearly healed. After a few days the wound again began to discharge pus. Short-wave treatment was again given, and again the discharge ceased. By this time the wound had healed. Later, it was observed that pus was exuding from a minute opening. The X-rays revealed nothing abnormal. The patient was then submitted to surgical treatment. The *second* case was in a girl of eight who had a septic ulcer on her leg which had developed after a scratch. It was completely healed by short waves, the treatment being given over a period of twenty-five days. The *third* was in a female of fifty-six. There was an indolent septic wound of the index finger which had developed after a dog bite. Short-wave treatment caused immediate relief of pain. Healing began after the third day. The *fourth* case was one of a painful traumatic ulcer of the ankle. Short-wave treatment quickly relieved the pain. Healing was slow. Granulations were abundant after seventeen days and at the end of a month the ulcer was almost healed. The *fifth* case, in a female of twenty-four, was somewhat similar. The ulcer was in a similar situation. It healed after a course of short-wave treatment lasting twenty-five days. The *sixth* case was in a female of twenty-four who had been left with an unhealed ulcer of the foot after an operation for cellulitis. After a course of short-wave treatment over a period of twenty-six days the healing was complete. The *seventh* case was in a male of fifteen. There was a discharging ulcer of the scalp. Under short-wave treatment its size gradually diminished but complete healing was not obtained. The discharge, though slight, persisted. The *eighth* case was in a male of twenty-six. Originally he had an abscess of the ring finger after injury. After incision the wound did not heal and there was much pain. After the second short-wave treatment the pain disappeared and healing began. After twelve days it was nearly complete. The *ninth* case was in a male of thirty-eight who had a painful indolent ulcer on the stump after amputation of a leg. Short-wave treatment relieved the pain but in other respects it was unsuccessful. Diathermy was equally unsuccessful. Slow healing was ultimately procured by means of iodine ionisation.

*Sepsis in Connection with Bone.* By reason of its low conductivity and the higher conductivity of the tissues around it, short-wave treatment should, theoretically, be suitable for periostitis, osteitis and osteomyelitis—if heat is a suitable therapeutic agent for them. The writer's experience in the treatment of diseases of this kind is very small. A man of fifty-five who suffered from periostitis of the mandible with discharge and pain was submitted to short-wave treatment. The pain was soon relieved. The discharge became almost unnoticeable but did not quite disappear. Afterwards it was found that each application caused a slight discharge of pus with a little blood for a day or two ;

then there was a quiescent period until the next treatment. This patient was ultimately referred for surgical treatment. A female of thirty-eight had suffered for two years from discharge from her right ear after a mastoid operation. After four bi-weekly applications of short waves her chief symptom—headache—almost completely disappeared but the discharge continued in spite of continuation of the treatment. A woman of twenty-two, formerly the subject of osteomyelitis of her left ankle, had developed pain and tenderness of the same region. Diathermic and short-wave treatment procured only short-lasting relief.

In regard to *osteomyelitis* the following quotation from Schliephake is interesting. "Judging from our experimental and clinical experiences the treatment of osteomyelitis would appear also very promising. In the patients treated by me under the supervision of the surgical department of the Virchow Hospital, Berlin (Professor Unger), the following was the general impression : In perfectly fresh cases of osteomyelitis, which showed no changes by X-rays, there was a complete remission of symptoms (fever, swelling, pain). In cases of longer standing, demarcation and sequestration were favoured.

"It is especially in cases where, owing to extensive dissemination with difficulty in delimiting the foci, and where the prospects of operative interference are unfavourable, that the outlook is improved by producing sharp demarcation. Generally speaking, it is the shortest waves (3–4 m.) which have been found beneficial and effective, but nothing final can be said on this matter."

*Nasal Sinusitis.* Five cases were treated. The *first* was in a woman of forty-three. There was much pain but no discharge. Discharge began after short-wave treatment was commenced and the pain was relieved. After bi-weekly treatment lasting for six weeks there was an apparent cure. The *second* was a case of very long-lasting frontal sinusitis in a girl of sixteen. It had existed since the age of two. During the past two years there had been an occasional discharge of blood. Short-wave treatment was without effect. The *third* case was in a woman of fifty-five. She had undergone operation eight months previously for chronic maxillary sinusitis. She was edentulous. She obtained only slight relief from short-wave treatment and no more from diathermy. The *fourth* case was also one of chronic maxillary sinusitis. The patient was a man of thirty who had originally undergone operative treatment. The discharge ceased under short-wave treatment and the pain disappeared. The subsequent report from the Throat Department was " nose quite clear and no discharge."

*Varicose Ulcers.* In the 4 cases received it was found that neither short-wave treatment nor diathermy did any good.

*Ophthalmic Cases.* A woman of sixty-eight who had developed iritis after operation for cataract, derived only slight relief from short-wave treatment which was given daily (eight applications). After six daily treatments by *diathermy* the pain was only slight and it disappeared after six more applications. The pain did not return after a fortnight's rest without treatment. The *second* case was one of secondary glaucoma in a man of fifty-eight. The pain went after the second short-wave treatment and did not return during the following seven weeks while he was under observation. The *third* case also was one of glaucoma, which had developed after hæmorrhage from the central artery of the retina. Short waves always produced great, but short-lasting relief. Finally the eye had to be removed.

*Dental Disease.* For the reason given under the heading of *Sepsis in Connection with Bone,* short-wave treatment should be of value in paradentosis. It is advised by Schliephake. He recommends the use of waves under 6 metres in length. The machines that generate waves of this shortness are extremely expensive and the English odontologist will await further experience by administrators of short-wave therapy. The writer treated (by 6-metre waves) 3 cases of chronic gingivitis, all of which derived no benefit.

*Other Cases.* A boy of 16 had suffered from *acne vulgaris* for ten months in various parts of the body. One part was treated by short waves and another by diathermy. Each form of treatment procured equal, but slight benefit. Two cases of *inflamed sebaceous cyst* were subjected to short-wave treatment. In one the inflammation subsided after the third treatment. In the other the treatment was without effect. In a very chronic case of *dermatitis* (since 1916) short-wave treatment and diathermy had no effect. A case of *mycosis fungoides* in a man of sixty-six, who had acquired the disease twenty years previously and had it all over his body, was treated by short waves in some regions and by diathermy in others. The swelling and redness lessened under each form of treatment, but there was no additional benefit. A case of *chronic suppurative mastitis* in a woman of thirty-two improved rapidly under short-wave treatment. The discharge disappeared after eleven days. After twenty days the breast was normal. Cases of *osteo-arthritis* of the hip and other joints responded to short-wave treatment in the same manner as to diathermy. Benefit gained from diathermic treatment was not increased by short-wave treatment and *vice versâ*. Cases of *catarrh of the upper air passages* are not sent to the electrical department. A private patient who suffers from severe colds about twice each year began to develop one three days before the time when he had to make a speech in public. He had recently read about short-wave treatment in the Press. He came to the writer and said he would like to try the treatment. The cold was aborted in two days.

*Cases of Disease of the Thoracic Organs.* Both by diathermy and by short waves the writer has been able to diminish the frequency and severity of the attacks in bronchial asthma during the time when the patients were under the treatment. In a case of bronchiectasis, in a male in-patient of twenty-six who underwent short-wave treatment, the sputum was reduced to about one-third of its former amount. Diathermic treatment procured no further result.

*Gynæcological Cases.* Efforts have been made to cure or alleviate inflammation of the uterus, its adnexa, and the pelvic supporting tissues by the short-wave method. The large amount of fat and bone in the abdominal and pelvic walls and the small size of the uterus, tubes and ovaries do not favour the production of heat in these organs. Condenser electrodes have recently been devised for introduction into the vagina and the production of higher degrees of heat within the pelvis. But it is unlikely that they will replace the simpler methods of treating the cervix and urethra by the diathermic current. In these methods much simpler electrodes are placed *inside* the parts mentioned, known temperatures are obtained and the dosage is exact.

In the treatment of inflammation of the tubes, ovaries and pelvic supporting tissues by the *short-wave method*, Dr. Justina Wilson informed the writer that she has obtained excellent results, similar to those obtained by Dr. Schuhmacher, who has treated 150 cases during the last year and will publish his experience in a short time.

It must be remembered, however, that general intra-pelvic heating can effectively be practised by the diathermic current, and its value has been established by experience in this country lasting over a period of at least seventeen years.

In regard to *angina pectoris* and *hypertension* a perusal of the Chapter on Diathermy in the Treatment of Diseases of the Cardiovascular System will show the beneficial results obtained in the treatment of the disease named by diathermy. Dr. Wallace Jones, the writer of that Chapter, has contributed the account below of his experience in the treatment of angina pectoris by short waves.

*Concluding Remarks.* The writer would conclude from a relatively brief experience that in superficial disease, and in disease that is not deeply situated, there appears to be little difference between the results of diathermic treatment and those obtained by short waves, although the technique practised renders the latter more comfortable for the patient and much easier for the practitioner. But it is in cases of deeply situated disease in the thorax, head and abdomen that short-wave treatment is hoped to succeed where diathermy has failed, or is less effective. Perusal of the following article by Dr. Wallace Jones may lead to the belief that the hope is justified, as far as the heart is concerned.

## SHORT-WAVE DIATHERMY IN ANGINA PECTORIS

BY

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Since the introduction of ultra-short-wave diathermy during the last few years it has been applied to many of those conditions which were previously treated with the older long-wave diathermy. It has been found that not only does it benefit to an even more marked degree those conditions, but that it has certain additional applications which could not be treated with the old type of diathermy. It was not until 1932 that Meyer (1) first applied this short-wave diathermy for the treatment of angina and this was followed a few years later by a joint paper with Laubry and Walser (2) in which their experience of 20 cases, treated by this method, were recorded. They used a wavelength of 16 metres, the patient being placed between the electrodes, one electrode being placed at the level of the second costo-sternal junction of the left side in front and the other one near the second dorsal spine behind. They used small electrodes, each being between 10 and 16 cm. in diameter. They used a current of ½ to ¾ of the thermic ampere and each treatment lasted from ten to twelve minutes. Treatments were given every two or three days and most of the cases had a course of six to twelve treatments.

They concluded that short-wave diathermy was excellent for the angina of effort and had 11 successful cases out of a total of 15. They found that when the angina occurred apart from effort the results were not so good. When the results were compared with those obtained from the old type of long-wave diathermy they concluded that the short-wave diathermy was much superior to the old type, in that it was not only more efficacious but in addition very much easier to manage. They also recorded that 3 of their cases which had been treated by the old type of diathermy with the usual benefit improved much more when treated by the short-wave diathermy.

Similar experiences were also recorded by Giroux and Dausset (3) who treated 7 cases of angina, 5 of which were examples of the angina of effort, with short-wave diathermy. They used a current of 300 to 400 watts and the treatment lasted twenty minutes to half an hour; it was continued every other day and the total number of treatments varied from six to twelve. They found that especially in the cases of the angina of effort the improvement was marked and very often occurred in those cases which had been resistant to any other form of treatment. They also noted that the results seemed to persist for some time after the treatment had been stopped.

As short-wave diathermy has only been in use in this country for a comparatively brief time I have not had experience in treating a large number of these cases, but I have records of 14 cases of angina which have been treated in this way. In treatment of these cases we made use of Standard Cox Spark-Gap Ultra-Short-Wave Machine. The wavelength used varied from 9 metres to 12 metres and the application was through the chest, front to back. The size of the electrodes was 6 in. by 6 in. and the amount of current was 100 to 200 watts, and the number of treatments varied from six to eighteen, as a rule at two or three-day intervals.

It is, of course, very difficult with a small number of cases of this kind to speak dogmatically, but when one compares our experience of the treatment of angina of effort by the long-wave diathermy with that obtained in the short-wave therapy it would appear that the latter is far more rapid in its action and more beneficial than the old type of treatment. The patients seem to improve their cardiac reserve power much more quickly than they did under the old method and this is especially manifest in those cases which fall under the class of the angina of effort.

Four of these cases with angina of effort, combined with a high blood pressure, had been under treatment with the old long-wave diathermy for a considerable time before having a course of treatment with the short-wave therapy. In 3 of these cases the improvement with the short-wave diathermy was marked and they all expressed the opinion that this type of treatment was a distinct improvement on the old type of diathermy. In the fourth case there was no material change in the patient's condition.

With regard to the changes in the blood pressure there appears to have been, as before, a slight fall after treatment. The chief result is in the feeling of well-being in the patient and also the marked increase in the cardiac reserve power. In some of the cases the pain completely disappeared after a few treatments.

We also tried the effect of short-wave diathermy on cases of hypertension alone without any cardiac pain.

We first used the electrodes to the chest, front and back, but our results were disappointing and the effect produced on the blood pressure was very slight and in some cases a rise in pressure occurred, and the subjective sensations of the patient did not seem to improve. We therefore tried the effect of placing the electrodes so that both the carotid sinuses came into the field of radiation. We have tried this method of treatment on 5 cases of high tension alone without any cardiac pain. Under treatment, as a rule, there is a slight fall of pressure which remains for some hours and then tends to rise again slightly. When the treatment is undertaken every other day there is a fall in the average pressure, though usually this fall is not very marked. These results do not show any marked improvement on those obtained in cases of hypertension with the old type of

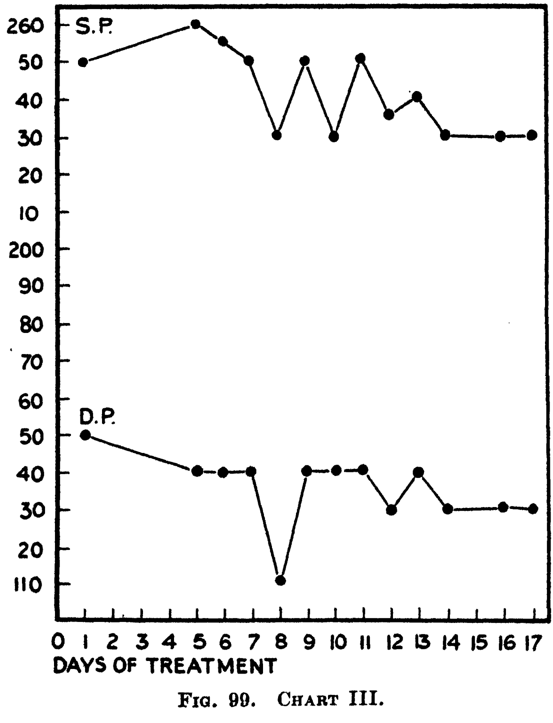

FIG. 99. CHART III.

diathermy, and I think that part of the difficulty in treating cases of hypertension by the short-wave machine is that one can no longer produce the effect by sending the current along both arms or both legs as one did in the old method, producing the effect of heating chiefly the tissues having the lowest resistance, *i.e.*, the blood vessels.

Short-wave therapy with its more concentrated field and better penetration of the tissues has the advantage, in the treatment of angina, of more direct action on the coronary circulation and less of the " poultice effect " of the older long-wave treatment. It has, however, correspondingly certain disadvantages in the treatment of hypertension.

*Case* 9. A woman, aged 43, with symptoms of throbbing in the head and feeling of giddiness for the last seven years : blood pressure 250/150 mm. Hg, no cardiac enlargement : soft systolic bruit at the base of the heart. Urea concentration test, 4·3 gm. per cent., moderate amount of albumin in the urine.

Short-wave diathermy treatment, 7 metres, 2 amperes, daily applications through the neck at the level of the carotid sinuses lasting fifteen minutes. This was continued for fifteen days in all and the effect on the blood pressure is shown by Chart III. Subjectively she improved very considerably though the actual fall of blood pressure was not very marked.

*Case* 10. A man, aged 57, blood pressure 130/80 mm. Hg, tight feeling of pain across the chest on exertion. Pain radiates down both arms and to the side of the face ; some shortness of breath also on exertion. Heart not enlarged, sounds distant, no bruits, electrocardiogram : inverted " T " wave (leads I. and II.) with left ventricular preponderance.

Short-wave diathermy, seventeen treatments, 9 metres, 2 amperes, fifteen minutes' session. After the first treatment he experienced a feeling of exhilaration and after four treatments began to sleep better and found he could undertake some exertion without getting the pain. At the end of seventeen treatments he was discharged from hospital completely free from pain and he returned to his work—that of a school-master.

## REFERENCES

(1) Meyer, J. *Annales de l'Institut d'Actinologie*, November, 1932.
(2) Laubry, Meyer, and Walser. *Bull. and Mémoires de la Soc. Méd. des Hôpit. de Paris*, 1933, Vol. 49, p. 1290.
(3) Giroux and Dausset. *Bull. de l'Academie de Méd.*, 1934, Vol. 3, p. 54.

# SECTION IV

# INDUCTOTHERMY

## CHAPTER XXVI

## INTRODUCTION

THE word *inductothermy* has been selected as a name for the heat that is generated in the body by high-frequency currents by the process of *induction.* The induced currents, or " eddy currents," as they are frequently called, overcome the ohmic resistance of the tissues and produce heat. The body itself is not included in the circuit of the inducing current. On the other hand, in the form of treatment to which the name *diathermy* is given, without any additional prefix, the body is part of the circuit of the current generated by the machine, and the heat is generated by the current in overcoming the ohmic resistance of the tissues. In short-wave treatment the body is likewise included in the circuit of the machine that generates the current, and the heat is produced, not only by overcoming resistance, but also through the loss of energy that occurs in those tissues that, by reasons of their poor conductivity, act as dielectrics.

Treatment by inductothermy is the most recent of the electrothermic methods.

### Historical Note

In principle, treatment by induced high-frequency currents is not new. In the " nineties " of last century the subject was investigated by Professor d'Arsonval, who introduced a method of administering high-frequency currents to which he gave the name *auto-conduction.* In this method the current oscillated in a bobbin coil of stout wire. The turns were widely spaced, and the coil was large enough to enclose the entire body without touching it. The coil was suspended with its long axis vertical and the patient stood within it or sat on a high stool within it, in a nearly vertical posture. The body acted as a conductor and the main current in the coil induced other currents of the same frequency in the tissues. By employing a main current of considerable intensity, d'Arsonval was able to demonstrate the induced currents by making them illuminate a filament lamp which was placed in circuit with the body.

Treatment by auto-conduction was practised a good deal in France during the first decade of the present century. But when the nature of the treatment, afterwards called diathermotherapy, was understood the original method of practising auto-conduction fell into disuse. In its place a diathermic machine was used and a much smaller coil—capable of including merely an extremity or the head—was connected to it. This way of administering diathermy is little used.

The development of the inductothermic method took place in the United States in the research laboratories of the General Electric Company. About eight or nine years ago the medical officer in charge of the hospital attached to the Schenectady branch of this company observed that the workers in a particular section of the factory were prone to feel ill towards the end of the day's work, and develop a mild degree of pyrexia. The usual rise of temperature was about 1° F. The cause was eventually traced to the presence of high-frequency fields around the special machines used for heating the internal metal structures of wireless valves *in vacuo*. Further trouble was prevented by magnetic shielding. The idea then occurred to construct a machine for the purpose of raising the temperature of the body, in high-frequency fields, with the object of treating disease by means of heat.

About 1930 a machine which was called a " radiotherm " was produced for the purpose of raising the temperature of the body as a whole. The body was placed in a condenser field, the principle being the same as that described in the Section on Short-wave Therapy. It was not an " inductothermic " method. By reason of the risk of producing burns of the skin when general pyrexia was being brought about the use of the " radiotherm " was discontinued. Further investigations were made and ultimately the inductothermic method of heating the body was devised. About four years ago the first inductotherm machines began to be employed for the purpose of producing therapeutic fever. In the United States they are used almost universally for this purpose. They are being increasingly used in this country for the same purpose. They are also employed for local treatment.

## The Inductotherm

This machine is illustrated in Fig. 100. It can be mounted, if desired, on a cabinet provided with castors. It contains a single triode valve. The current delivered by the machine is generated on the principle already described. It has a frequency of 12,000,000 cycles per second. A plan of the machine is shown in Fig. 101.

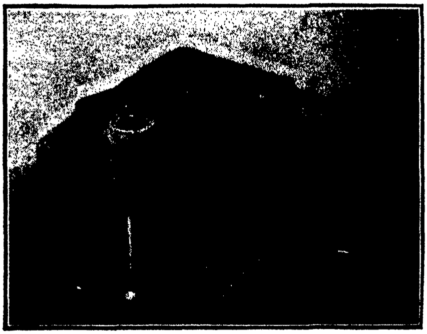

FIG. 100.—The Inductotherm.

In order that the electrical energy yielded by the machine may be used for heating the body a long flexible cable, specially made for the purpose, is used. This cable is about 12 ft. in length and $\frac{3}{4}$ in. in thickness. It consists of a central stranded wire in an insulating covering made of soft grey rubber. At each end is a metal plug. There are two separate sockets at the back of the machine for the insertion of the metal plugs. Their insertion completes the oscillating circuit. This cable takes the place of the primary oscillating coil of the ordinary diathermic machine. There is no secondary oscillating coil (resonator).

When treatment is to be given, the cable is wound, before its ends are inserted, so as to take the shape of a

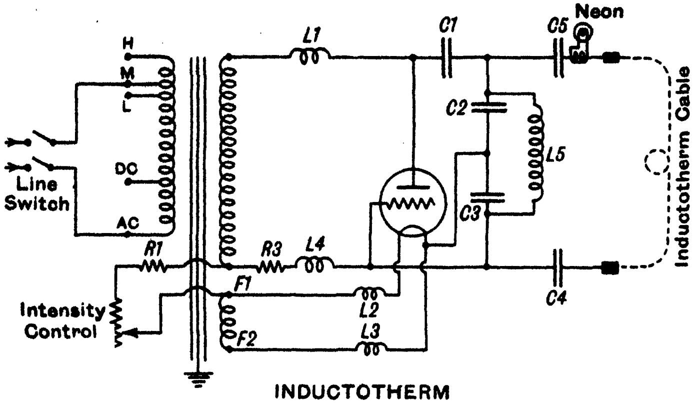

FIG. 101.—Plan of Circuits in the Inductothermic Machine.

spiral and, at the same time, leave a couple of feet or more unwound so as to bridge the distance between the machine and the patient. The spiral may be made flat, cylindrical

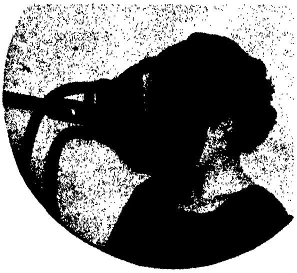

FIG. 102.—Casing containing Portion of Cable of Inductotherm wound in form of a Flat Spiral.

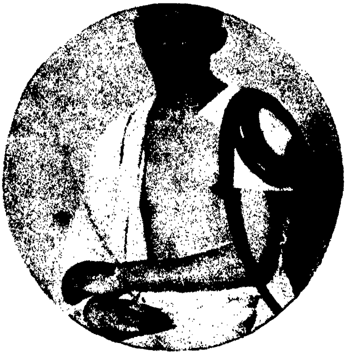

FIG. 103.—Cable of Inductotherm applied to Shoulder.

or conical, according to the region to be treated. As a flat spiral is so often employed, the makers provide one which is mounted within an ebonite casing. The casing is attached by a movable joint to the end of a wooden pole, which is adjustably supported on a tripod stand. If the machine is mounted on a cabinet the stand may be fixed to the cabinet on which the machine is mounted. One of these ebonite casings containing the portion of the cable wound in the form of a flat spiral is illustrated in Fig. 102. The cable wound in somewhat conical form is illustrated in Fig. 103. In Fig. 104 the cable is wound in the form of a helical spiral. In Fig. 105 the cable is wound in the form of two flat spirals, one on the anterior aspect, and the other on the posterior aspect, of the abdomen. The cable takes the form of a half-loop in Fig. 106. It is close to the leg on each side.

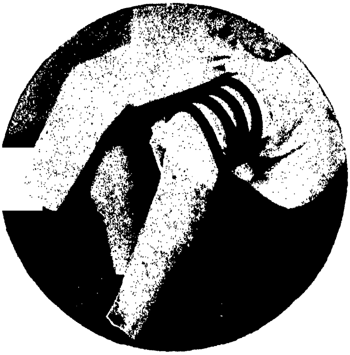

FIG. 104.—Cable of Inductotherm Wound around part of Thigh.

FIG. 105.—Cable of Inductotherm in form of two Flat Coils against Trunk.

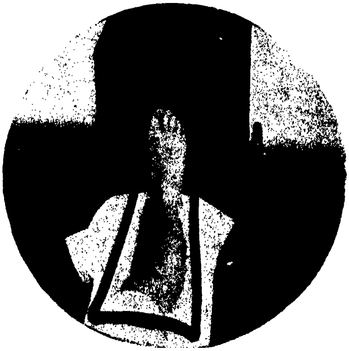

FIG. 106.—Cable of Inductotherm in form of a Half-loop.

## The Inductotherm in Operation

When the machine is connected to the main A.C. supply the ends of the treatment cable should be inserted in their respective sockets before the switch (visible in Fig. 100, on the top of the case in front) is opened. If this precaution is not taken the valve may be damaged. When the switch is opened the current oscillates in the cable and creates an electro-magnetic field around it. This field alternately appears and disappears with the same frequency as that of the oscillation of the current in the cable. The strength of the field can be progressively increased by increasing the strength of the current in the cable. This is done by rotating the control handle (seen in Fig. 100 on the top of the case behind the switch). Whatever the strength of the current may be the magnetic field can be intensified by winding the cable into the form of a spiral. The existence of the field can be demonstrated by placing a neon lamp close to the cable and seeing it glow. It is instructive to observe the different degrees of intensity of the field in the vicinity of the coil wound in different forms.

## The Induction of Eddy Currents in the Body

It is well known that a rising and falling electro-magnetic field causes currents to appear in conductors that are placed in the field. If the conductor is a closed circuit of wire the induced currents are guided, as it were, along this circuit. But if the conductor is a single mass of substances of different degrees of conductivity the induced current will distribute itself in different parts of the conductor. We may speak, in fact, of currents, each one independent of the other. They are called *eddy* currents because they call to mind the eddy currents in a river where the main stream is impeded by a number of boulders.

The human body is a massive conductor composed of tissues of different degrees of conductivity. When it is placed in a changing magnetic field the eddy currents will appear in it. In the better conducting tissues they will attain a greater intensity than in the tissues that have a lower degree of conductivity. Consequently the tissues that have a higher degree of conductivity (*i.e.*, a lower resistance) may attain a higher temperature than those which have a higher resistance. In this way the inducto-thermic method tends to procure a distribution of temperature which is different from that brought about by the other electrothermic methods. The diathermic current has to pass through the highly resistant fat and it heats this tissue to a higher degree than the others. In the short-wave method, too, the fat attains the highest temperature. It must not be forgotten, however, that the electro-magnetic field attains its maximum intensity in the region which is closest to the wire in which the current oscillates. In the case of the body the tissue which is nearest to the cable electrode (apart from the skin) is the subcutaneous fat. Consequently the tendency of the eddy currents to attain a feebler intensity in the subcutaneous fat is, to some extent, counterbalanced. Although the *rôle* of the fat in the superficial fascia is doubtless an important one in health, its presence is a handicap to treatment by the three important medical electrothermic methods.

### Advantages of the Inductothermic Method

It is now generally agreed that this method is better than the others for producing therapeutic fever. In the first place it is much safer. The risk of producing burns is almost negligible. Secondly, it is much simpler to practise, and much less time is occupied in applying the coil to the body than to fix electrodes in position. In the administration of local electrothermic treatment by the inductothermic method there is likewise the same simplicity and the same saving of time. There is no need for the patient to remove clothing that does not contain metal. The coil should not make contact with bare skin. It should be separated from it, if it is uncovered, by a dry folded towel about ¼ in. in thickness.

On the other hand, it is not possible, by the inductothermic method, to restrict the heat to a small part such as the eye, frontal sinus, etc. Nor is it possible to introduce the coil into the interior of the pelvis.

### Heating by the Inductothermic method compared with the Short-wave Method

When a conductor that has a specific inductive capacity greater than that of the air is placed in a condenser field it must be remembered that the field will be distorted. If a region of the body is included in the field it is not possible to foretell the amount to which it will be distorted. For this reason the operator is unable to judge which tissue will receive the maximum or minimum degree of heating. On the other hand, there is no distortion of the electromagnetic field. Consequently there is no likelihood of producing a field of unduly high intensity, restricted to any one tissue, with the risk of overheating it.

It has already been stated that in the short-wave method of heating, the subcutaneous fat attains the highest temperature. Underlying parts, such as the muscles and viscera, are heated to a very much lower degree. The frequency of the oscillation would have to be much higher than the maximum value now employed in order to secure a more even temperature distribution. It has been found that a frequency of 350,000,000 cycles per second (0·85 metre waves) is necessary to produce maximum heating of physiological saline.

Again, when the diathermic current is used it is the subcutaneous fat that attains the highest temperature. The better conducting tissues under the superficial fascia are heated to a lower degree. Reasons are given in Chapter VII to show the unlikelihood of obtaining a rise of temperature locally in the depth of the trunk.

It seems, then, that the inductothermic method is more likely than the others to raise the temperature of the deep-lying organs of the trunk, though no proof by experiment has yet been obtained.

### Present Position

At the present time assiduous work is being conducted in Germany in the endeavour to prove that the short-wave method is the most efficient for procuring the deepest heating. In the United States the short-wave method has not attained a wide degree of popularity. Workers there are endeavouring to demonstrate the superiority of the inductothermic method for producing a rise of temperature locally in the deepest parts. In England, the diathermic method, with its twenty-five years' experience behind it, is still the most popular, at any rate for local treatment —in spite of the talk in other countries of its becoming obsolete. If the eyes of British workers are directed towards one country rather than another in order to see what is being done, it is eastwards rather than westwards, probably on account of the flair in Germany for propaganda.

## Therapeutic Field of Inductothermy

By reason of the safety of the patient from the risk of burns the use of the inductothermic method for producing therapeutic fever has replaced the diathermic and the short-wave method in the treatment of general paralysis in the United States, and it seems to be replacing diathermy in the treatment of the same disease in England. For the same reason a number of other diseases, that are notoriously irresponsive to therapeutic methods hitherto known, are being treated in the United States by general inductothermy—that is, by creating therapeutic fever by the inductothermic method. The work in that country has assumed colossal proportions and other physical methods, as well as electrical, are being used for the purpose. In 1935 a Fever Therapy Congress—the *fifth* of its kind—was held in Dayton, Ohio, under the presidency of Dr. W. M. Simpson, at the Miami Valley Hospital, Dayton.

Apart from its use in mental hospitals in this country the general inductothermic method is being employed sporadically in certain general hospitals. At St. Bartholomew's Hospital it has been used by George Graham in the treatment of bronchial asthma. Freedom from attacks for periods as long as nine months has been obtained.

The method has been more extensively used by W. Kerr Russell, at the Temperance Hospital, London. Up to March 18th, 1936, he had treated 49 cases. The diseases were disseminated sclerosis (24 cases), rheumatoid arthritis (12 cases), encephalitis lethargica and paralysis agitans (3 cases), cystitis due to *B. coli* (2 cases), gonococcal arthritis and urethritis (5 cases), bronchial asthma (1 case), chorea (1 case) and brachial neuritis (1 case). There was marked improvement in some of the cases of disseminated sclerosis, the spasticity being lessened and the gait improved. Some of the cases of rheumatoid arthritis derived relief; others were not improved. One case of paralysis was much benefited. The cases of cystitis showed great improvement—after a ketogenic diet had failed. In the case of chorea all movements ceased after the first treatment. The gonococcal cases were much improved.

It must be realised that pyretotherapy, *i.e.*, treatment by producing fever for therapeutic purposes, is no light undertaking. It cannot be practised except in a hospital or institute where experienced administrators are in attendance and a doctor within call during the hours while the patient is in a state of pyrexia. Continuous attention on the part of specially trained nurses is essential. Not all patients can be subjected to the treatment. Those who suffer from heart disease or have an unduly high blood pressure are unsuitable. The patient is enclosed in a bag made of waterproof material lined internally with lamb's wool. A blanket also is placed within the bag. On the bed are placed two mattresses, a mackintosh sheet and a blanket. The patient within the bag lies on the blanket with a rubber cushion under the head. The cable from the inductotherm is wound in the form of a flat coil which is placed on the bag. Additional blankets are placed over the bag. The machine is adjusted to give its maximum output and the switch opened. A period of two to three hours is occupied in elevating the general temperature to the degree desired. The oral temperature, also the pulse and respiration rate, are measured every fifteen minutes, and the rectal temperature is taken after the completion of each hour's treatment. If the temperature is rising too rapidly the current may be reduced and, if necessary, some of the blankets may be removed. After the general temperature has reached the desired value it is maintained at that figure for the desired number of hours. The current is switched off, and if the heat insulation of the patient is sufficient the temperature will not fall. At the end of the maintenance period the temperature is allowed to fall slowly by removing as many as necessary of the patient's coverings.

During the treatment the patient is allowed to drink iced water. It is necessary that he should be given 0·6 per cent. salt solution from time to time in order to compensate for loss of chlorides in the sweat during the treatment.

It is too soon yet to state the maladies for which therapeutic fever will be the standard treatment. In the treatment of gonorrhœa and its complications the workers in the United States appear to have obtained most satisfactory results, terminating the infection and arresting the complications. With the exception of anterior urethritis in men it must be remembered that equally successful results have been obtained in this country by local diathermic treatment, a procedure which is " less heroic " than general pyretotherapy and does not require stay in a hospital or institute. The local diathermic method has been in use for sixteen years and in certain hospitals it is regarded as the treatment of choice.

In regard to *local* inductothermic treatment it may be said that its field is the same as that of diathermotherapy. By reason of the simplicity of the technique and the saving of time it should play a useful part in hospitals where there are large and busy electrotherapeutic departments.

# PART III

## SURGICAL ELECTROTHERMIC METHODS AND THEIR USES

ELECTRODESICCATION (FULGURATION).

ELECTROCOAGULATION (DIATHERMIC COAGULATION: Surgical Diathermic Treatment).

ELECTROSECTION (ENDOTHERMIC KNIFE OPERATION, Arc-operation).

# CHAPTER XXVII

## INTRODUCTION TO SURGICAL ELECTROTHERMIC METHODS

THE surgical electrothermic methods are three in number. The *first*, and oldest, is one in which sparks are utilised for the purpose of destroying abnormal tissue. The name *fulguration* was originally given to it. Later, the technique was modified and the treatment was called *electrodesiccation.* It is known by this name in the United States, while in Europe it is generally called fulguration. In this form of treatment the action of the sparks is to deprive the tissue of moisture, *i.e.*, to *dry* it ; hence the name *desiccation.*

The *second* electrothermic method is one in which the tissue is *coagulated* by means of a diathermic current. This form of treatment was originally termed *electrocoagulation.* Afterwards it was called *diathermic coagulation.* The first name is used in the United States and the second in Europe.

The *third* method is one in which an electric arc is employed for the purpose of cutting tissue—the arc playing the part of a scalpel. In its original form the name *arc-operation* was given to the method. In its modern form the method is termed *electrosection.*

The forms of treatment conducted by the three above-described methods are termed *electrothermic* because their initial effects on the tissues—whether desiccation, coagulation or cutting—can be attributed to the action of *heat.* In each method the heat is generated by the current in overcoming resistance. Thus, when tissue is *desiccated*, the resistance is that of an air space between the point of a needle and the tissue under treatment. The current overcomes this resistance and forms thick sparks. The tissue derives heat from the sparks.

In *electrocoagulation* (*diathermic coagulation*) the resistance overcome is that of tissue under treatment. In overcoming this resistance the current generates heat within and throughout the tissue.

In *electrosection* the resistance overcome is that of a thin film of air between a fine wire and the tissue—the wire being embedded in the tissue. The current heats this film of air to incandescence, thereby enabling the wire to be moved in any direction and divide or cut the tissue.

While contrasting the three electrothermic methods it will be useful to indicate some other points of difference, viz., those of the *distribution* and the *degree* of heat that is generated in each method.

In treatment by *electrodesiccation*, the sparks represent air heated to incandescence. The heat derived by the tissue from the sparks, however, is sufficient only to evaporate, or occasionally boil, the tissue fluids. Only the superficial layer of tissue is heated at first. When it has been dried (desiccated) an underlying layer is heated. After it has been dried a third layer is heated and dried, and so on. There is no diathermy—in the strict sense of the word.

In treatment by *electrocoagulation* the tissue is heated to the degree at which the proteins coagulate. Frequently it is heated to a degree high enough to boil the tissue fluids. The heat is distributed throughout the tissue, *en masse*. This is true diathermy.

In treatment by *electrosection*, the temperature of the arc is extremely high. The cells in contact with the arc are perhaps exploded by the heat, but only a very thin layer (a fraction of a millimetre in thickness) around the arc is heated to a lethal degree. The distribution of the heat, therefore, is extremely restricted. There is no diathermy.

## Terminology

In the United States the expression " electrosurgery " is used as an inclusive title for the three electrothermic methods mentioned above. If it is taken to mean surgery by electrical methods it would include electrochemical cauterisation—a process in which tissue is killed by chemical caustics produced by the galvanic current. When high-frequency currents are employed the tissue is desiccated, cut or coagulated by *heat*. The name *electrothermic surgery*, therefore, would be a more complete title than electrosurgery. The use of a platinum loop, heated to redness by an electric current, for destroying tissue might also be called electrosurgery or electrothermic surgery. But when tissue is destroyed in this way the sole purpose of the current is to heat the platinum wire, the body itself being excluded from the circuit. In the other electrothermic methods the body is included in the circuit and the tissue is heated *directly*, either by the current or by the sparks or arc.

In order to avoid confusion arising from terminological multiplicity the author is of the opinion that the word *electrosurgery* should be adopted and used to signify the surgical methods in which high-frequency currents are employed either for the purpose of cutting tissue (electrosection), or for desiccating it (electrodesiccation), or for coagulating it (electrocoagulation).

# CHAPTER XXVIII

## DEFINITION AND MEANING OF TERMS

### 1. Electrodesiccation

*(Fulguration)*

Electrodesiccation and fulguration are the names given to a form of treatment consisting of the use of electric sparks derived from a high-frequency current generator for the purpose of killing abnormal tissue.

The literal meaning of electrodesiccation is *electrical drying*. The word calls attention to the fact that the electric sparks deprive the tissue of water. The expression *fulguration* (*fulgur*, lightning) denotes a supposed resemblance of the sparks to lightning on a miniature scale.

The name *fulguration* is more often used in Europe, while in the United States the name *electrodesiccation* is more popular. The word *fulguration* calls attention to the fact that the treatment is conducted by *sparks*. The word *electrodesiccation* conveys the information that the tissue is *dried* by the electric sparks. It may be said, then, that fulguration procures desiccation.

### 2. Electrocoagulation

*(Diathermic Coagulation: Surgical Diathermic Treatment)*

When a diathermic current heats tissue to a degree high enough to coagulate it—the heat being produced by the current in overcoming the resistance of the tissue—the procedure is termed *electrocoagulation* or *diathermic coagulation*, and the diathermy is said to be *surgical*. When the expression *diathermic coagulation* is used, the qualification *diathermic* calls attention to the fact that the heat is generated *throughout* the tissues. The qualification *surgical*, when applied to diathermy, implies that the degree of heat is high enough to kill the tissue, thereby contrasting *surgical* diathermy with *medical* diathermy.

### 3. Electrosection

(*Arc-operation : Endothermic Knife Operation*)

Electrosection may be defined as a surgical procedure in which an electric arc is employed for the purpose of incising tissue and cauterising the divided surfaces at the same time. It can be practised in a manner that will enable primary union to take place after the divided surfaces are brought together and sutured.

In the way in which it was originally conducted the procedure was termed " die Lichtbogenoperation " (the arc-operation). Primary union did not occur. Subsequently the apparatus and technique were improved and the name " operation by the endotherm knife " was suggested by G. A. Wyeth. At the present time most American surgeons use the term " electrosection," an expression which is now being adopted by many English surgeons.

The arc which incises the tissues is called a " cutting arc," and the current that produces the arc is called a " cutting current."

### PRINCIPLES UNDERLYING THE SURGICAL ELECTROTHERMIC METHODS

Those who are unacquainted with the principles on which the surgical electrothermic methods are based will more easily understand them if the following experiments are described.

A mass of raw meat is placed on a metal plate. This plate, which serves as an indifferent electrode, is connected to one of the terminals of a diathermic machine. The active electrode is a steel needle mounted on an insulating holder. It is connected to the other terminal.

The machine is set in operation and adjusted to give its full output. The point of the needle is brought gradually closer to the meat. When it is fairly close a torrent of thick sparks will pass between the meat and the needle.

The portions of meat on which they fall are instantaneously whitened and then dried or desiccated. This is the principle underlying *electrodesiccation.*

In the next experiment a narrow disc is used as the active electrode. It is placed in *contact* with the meat before the machine is set in operation. The machine is adjusted to give about one-half of its full output and then the switch is opened. After a few seconds the meat in contact with the disc alters in colour and becomes pale. It has been *coagulated* by the current. This is the principle underlying *electrocoagulation* (*diathermic coagulation*).

In the third experiment a short narrow blade is employed as the active electrode. The machine is adjusted to give nearly its full output and the switch is opened. The blade is brought up to the meat. Sparks pass when it is close, and they assume the character of an *arc* when the point of the blade is almost in contact with the meat. Without delay, the blade is inserted into the meat and drawn across it, as in making an incision. The arc is not extinguished when the blade is inserted or when it is drawn across the meat. It cleaves the tissue apart. At the same time it whitens the divided surfaces. This is the principle underlying *electrosection.*

If the human body were included in the circuit in place of the meat it would be possible to desiccate, coagulate or cut abnormal tissue in the manner just described. When the operation of *electrocoagulation* is performed the technique is not very different from that described above. But in treatment by *electrodesiccation* or *electrosection*, in the ways in which they are practised to-day, we require special current generators, and the technique is modified and more elaborate.[1] Details will be given later under their appropriate headings.

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[1] In the original crude methods the generators resembled the modern diathermic machine, and the technique was not unlike that described in the experiments on the meat.

# CHAPTER XXIX

## HISTORY OF THE DEVELOPMENT OF THE SURGICAL ELECTROTHERMIC METHODS

### 1. Electrodesiccation

As far back as 1894, Oudin,[1] a French worker, described a method of killing benign growths by means of sparks derived from the high-frequency resonator which was named after him. [A brief account of a resonator of this kind is given in the Section on Effluvation and Étincellage (p. 304), and one of the same type is illustrated in Fig. 91, p. 308.]

In 1900, Rivière, of Paris, made a communication entitled " Action des courants de haute fréquence et des effluves du Resonateur Oudin sur certaines tumeurs malignes et sur la tuberculose " to the International Medical Congress held at Paris in the year stated. He used a method similar to that of Oudin.

In 1906, de Keating-Hart, of Paris, communicated to the International Congress of Electrology and Radiology at Milan a paper on the use of " *L'étincelle violente* contre le *vrai cancer*," and described the results which he had obtained during the previous year. He used powerful apparatus and longer sparks than those employed by Oudin and Rivière. In 1909 he published a monograph, " La fulguration et ses résultats dans le traitement du cancer d'après une statistique personelle de 247 cas." It was he who introduced the term " fulguration."

In the same year, Doyen, of Paris, employed sparks that were shorter but more intense than those previously used. In 1910 he communicated to the Congress of Physiotherapy, held in the same city, a paper entitled " Traitement local des cancers accessibles par l'action de chaleur au-dessus

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[1] *Bull. de la Soc. de Dermatologie*, August 3rd, 1894.

55°." He described two methods of employing high-frequency currents for destroying malignant tissues.

In the *first*, which he termed "voltaisation bipolaire avec étincelles," the destruction was effected by sparks. A large metal electrode (indifferent) was applied to the patient and connected to one end of the resonator of a powerful d'Arsonval transformer. The active electrode terminated in a metal point. It was connected to the other end of the resonator. It was brought close to the tissue to be destroyed. Sparks of considerable intensity passed on to the tissue and carbonised the surface layers. Under the carbonised portion the tissue was destroyed to a slight depth.

The late W. L. Clark, M.D. (From *Archives of Physical Therapy, X-Rays, Radium*).

In the *second* method, a small metal disc was used instead of a pointed metal rod and it was placed *in direct contact* with the growth. Therefore the current did not pass in the form of sparks. Being of much greater intensity than that utilised in the first method it heated the tissue to a degree high enough to cause it to coagulate. This form of treatment was the forerunner of diathermic coagulation.

To French workers must be given the credit of devising the method of destroying abnormal tissue by means of sparks. But in France the treatment fell into neglect, or even disrepute, because it was practised mainly in cases of malignant disease and the results did not justify the claims. In the United States the method was independently investigated and tried in cases of non-malignant disease. It was in that country that its usefulness was first established. In 1907, F. R. Cook,[1] in an article entitled "The High-frequency Metallic Discharge: a New Treatment; its

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[1] *Med. Rec.*, New York, 1907, lxxii, 1017.

Possibilities," he described the use of sparks from a high-frequency current generator for the destruction of enlarged tonsils, papillomata and other forms of abnormal tissue. But it was the work of W. L. Clark,[1] of Philadelphia, who conducted a lengthy series of investigations on the subject and devised a satisfactory technique, that established the value of the method. In 1909 he described the procedure he had been practising during the previous three years. By reason of the fact that tissue subjected to the action of the sparks was rendered dry he devised the name *electro-desiccation* for the treatment.

## 2. Note on the History of Electrocoagulation

The form of treatment now known as electrocoagulation, or diathermic coagulation, was first practised by Nagelschmidt.[2] At a congress held in Budapest in 1908 he demonstrated the coagulation of albumin and liver by the diathermic current. Two years later, at a congress held in Berlin, he showed a number of cases of lupus vulgaris which he had treated during the past two years. This congress was held in May, 1910.

In France, coagulation of tissue, by a high-frequency current, was demonstrated by Doyen at a meeting of the Congress of Physiotherapy which was held in Paris in 1910. A current of considerable intensity, derived from a d'Arsonval transformer, was employed, and the active electrode—a small disc—was placed *in direct contact* with the tissue. In principle the method was the same as that which had already been devised by Nagelschmidt. Doyen named the method " electrocoagulation," while Nagelschmidt used the expression " surgical diathermy."

It will be remembered that the method of action of high-frequency currents in raising the temperature of the tissues was not clearly understood until Nagelschmidt correctly explained the phenomenon.

Earlier in the present volume it was stated that Nagelschmidt visited the electrical department of St. Batholomew's Hospital in 1910 and gave the first demonstration in this country of diathermic coagulation. Owing to the work of Douglas Harmer and the excellence of the results obtained by him in cases of malignant disease of the upper air passages, the employment of diathermic coagulation by laryngologists in London, and afterwards in other parts of England, gradually increased. In fact, its use was more general in London than in Berlin. In recent years, however, it seems to have fallen somewhat into abeyance, probably on account of the present-day popularity of radium.

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[1] *New York Med. Jour.*, 1911, xciii, 1131.

[2] *Münch. med. Wochenschr.*, 1910, No. 50.

### 3. History of the Development of Electrosection

Electrosection is founded on experimental work originally conducted by Lee De Forest,[1] who showed that tissue could be divided by directing sparks from a high-frequency current generator on it from a needle, the needle being moved into and across the tissue while the sparks were passing. It was thought that this method might be used in surgery, not solely to obtain incisions, but mainly to procure coagulation of the divided surfaces and thereby seal the divided ends of vessels. In 1910, V. Czerny,[2] of Heidelberg, and E. Eitner,[3] of Vienna, utilised the method in surgical practice and the name " lichtbogenoperation " was given to it. With the apparatus then available it had certain drawbacks, its chief defect being the inability to obtain primary union of the divided surfaces after they were sutured together. This " arc-operation " was practised sporadically on the Continent during the second decade of the present century and little headway was made. But in the third decade progress of great importance took place. Special apparatus was devised, the technique was refined, the method was increasingly employed and a " new surgery " came into being. Two names must receive special mention in connection with these advances. John Anderson, of Dundee, and George Wyeth, of New York, must be regarded as the creators of present-day electrosection.

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[1] Lee De Forest, the distinguished graduate in science and physics of Yale University, U.S.A., made a number of inventions, the most important being the audion amplifier which made long-distance wireless telephony possible. It was he who introduced the grid electrode into the Fleming valve, thereby making possible the great achievements of the three-electrode valve. During the past fifteen years he has been working on the development of the talking motion picture.

[2] *Dtsch. med. Wochenschr.*, 1910, No. 11.

[3] *Wien. klin. Wochenschr.*, 1910, No. 5.

The late John Anderson, formerly surgeon to the Royal Infirmary, Dundee, informed the writer that he first saw the "arc-operation" in the Clinic of Gosta Forssell, at Stockholm, in 1923. On his return to Dundee he performed experiments with various generators. Amongst others, he employed a machine of a type which was originally constructed for connection to a *direct* current main.[1] This machine happened to provide a current which had a closer resemblance to those now employed than the ordinary diathermic current and it had a correspondingly higher degree of efficiency. Whereas the diathermic current produced long thick sparks rather than an arc, the current from the other machine yielded a true arc which severed the tissue with the greatest ease and cauterised the divided surfaces to a much slighter depth. He began to employ it for the purpose of excising malignant growths, especially those of the breast. He did not publish his results, however, until 1928. His paper was entitled "Surgical Diathermy in Breast Cancer,"[2] and it was published in the *British Journal of Surgery* (Vol. XV., 1927–28).

The late John Anderson, D.S.O., M.B., F.R.C.S. (Ed.). (*Photo: Drummond Young.*) (*The Lancet.*)

He continued his investigations during the next six years, employing new generators after they were designed, and utilising the cutting arc in the surgical treatment of other diseases. His researches were unfortunately brought to an end by his untimely death in 1935.

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[1] This machine was originally designed by Schall & Son Ltd., in order to provide a diathermic current for workers who had access only to a *direct* current main and were without a rotary converter for obtaining a supply of *alternating* current (A.C.). It is not regularly employed at the present time.

[2] The use of the words *surgical diathermy* would create the impression among those who had not read the paper that the growths had been coagulated *en masse* by a diathermic current. It will be learnt that a current passing in the form of an arc does not produce diathermy. The heat of the arc is restricted to the tissue in the closest vicinity to the arc.

In England the method was slow in reaching the capital. But in Manchester, A. H. Burgess, now Emeritus Professor of Clinical Surgery, Victoria University, was quick in seeing its value. Adopting the method, he practised it on an increasingly wide scale. His work has played an important part in the development of the new surgery in the British Isles.

George A. Wyeth, aware of the principles of the original arc-operation, and its defects, gave instructions for the design of special generators, and experimented with each one after it was constructed. Ultimately he obtained a machine that could yield efficient arc-producing currents. The arc could be adjusted so as to cauterise the divided surfaces to different depths. After a thorough trial of the use of the cutting arc for surgical purposes he described the method and his results at a meeting of the Surgical Section of the New York State Medical Society in April, 1924. This communication was published in May, 1924, in *The American Journal of Electrotherapeutics and Radiology*.[1] He named the method "operation by the endotherm knife." It attracted the immediate notice of Howard Kelly, the well-known Baltimore surgeon, who proceeded to learn the method and make extensive use of it. Other well-known American surgeons followed his example and the value of electrosurgery was established in the United States.

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[1] Wyeth, G. A., "The Endotherm," *American Journal of Electrotherapeutics and Radiology*, New York, 1924, xlii, 186.

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# CHAPTER XXX

## CURRENTS REQUIRED FOR THE DIFFERENT SURGICAL ELECTROTHERMIC METHODS

THE currents employed in each of the surgical electrothermic methods have one feature in common : they all oscillate with high frequency. But in other respects they differ.

For use in *electrocoagulation* (*diathermic coagulation*) the current has the same features as that employed in the practice of medical diathermic treatment. The frequency of the oscillation is 1,000,000 or less cycles per second ; the oscillation need not be quite sustained ; it is derived from a relatively low voltage and it reaches a high amperage under load. It will be called a *coagulating current.*

For the purpose of treatment by *electrodesiccation* a higher voltage is required because the current has to pass across air spaces which may be as long as ½ in. or more. In passing across these spaces (in the form of sparks) the amperage in the circuit is reduced to a value too low to be measured by ordinary instruments. The frequency of the oscillation does not seem to matter, as long as it is high. The oscillation need not be sustained. The current that produces the sparks will be called a *desiccating current* and the sparks will be called *desiccating sparks.*

For the purpose of producing the arcs best suited for *electrosection* the frequency of the oscillation is usually higher than in the case of the diathermic current. It may be as high as 5,000,000 cycles per second. It is essential that the oscillation should be *sustained.* The voltage is lower than that which produces a diathermic current. The current will be called a *cutting-current* and the arc a *cutting-arc.*

The reasons for these requirements will be better appreciated when the electrothermic methods are described in detail. The meaning of " sustained oscillation " and other terms is described in Chapter IV.

# CHAPTER XXXI

## WHY TISSUE CAN BE COAGULATED, CUT OR DESICCATED

It is by the production of *heat* that the high-frequency currents employed in the different electrothermic methods are able to coagulate, cut or desiccate tissue. In each method the heat is produced by the current in overcoming resistance. But, as shown below, the situation of the resistance, the degree of the heat, and the distribution of the heat are not the same in the different electrothermic methods.

### 1. Electrocoagulation

It has already been explained that a diathermic current generates heat in the tissues by overcoming their resistance. By using electrodes of large area the density of the current is maintained at a low value and the degree of the heat is insufficient to harm the tissues.

To coagulate tissue by the diathermic current a temperature of at least 60° C. is necessary. In the performance of the operation higher degrees of heat are often obtained and the tissue raised to a temperature of 100° C. or a little higher, at which the tissue fluids are raised to the boiling point.

To attain these temperatures the density or " concentration " of the current must be increased ; in other words, its lines of flow must be concentrated in a narrow path. This is effected by reducing the area of *one* or of *both* electrodes. Thus, if an electrode of, say, 1 sq. cm. in area is placed in contact with the abnormal tissue and the circ [illegible] current completed by applying another of, say, 2 [illegible] cm. to some distant part of the body, the density of the current will be very high in the region immediately under the small or *active* electrode, and very low in the vicinity of the large or *indifferent* electrode. The highest temperature will therefore be attained in the tissues in contact with the active electrode and the lowest in those which make contact with the indifferent electrode. The tissues in contact with the active electrode can be heated to 100° C. or higher, while those under the indifferent electrode are only slightly warmed. The temperature will progressively diminish as the distance from the active electrode is increased until, at a certain depth below this electrode, it will be insufficient to coagulate the tissues. The actual depth depends on certain factors which will be considered in due course.

### 2. Electrodesiccation

The introduction of the air space between the point of the electrode and the body has the effect of reducing the strength of the current to a low value. Most of the electrical energy is utilised in heating lines or trains of molecules of atmospheric gases to incandescence—thereby creating *sparks*. The sparks heat the *surface* of the body. Below the surface the current passes in the same manner as in an electrolyte. Although its strength, as stated, is low, its density is high in the points of tissue just below the surface because it " enters " along fine lines. The sparks at the surface play the part, in fact, of minute electrodes. The current oscillates in the extra-cellular fluid and heats it to a degree high enough to kill the cells and afterwards dry them. When a layer of tissue has been dried the current passes through it in the form of sparks. Then the layer immediately under the dried layer is desiccated. The same events occur in successively deeper layers.

As a desiccating current has so low an intensity it is incapable of producing diathermy. The tissues, other than those subjected to the thermic action of the sparks, are not heated. For this reason it is inexact to use expressions such as " diathermic desiccation " and " diathermic fulguration."

### 3. Electrosection

Why the formation of an arc enables the wire to be inserted into tissue without being extinguished, and to be moved in any direction without resistance is not known with certainty. The true explanation is not a matter of much importance. It may be assumed that the intense heat of the arc instantaneously vapourises the tissue fluid immediately ahead of it and around it, thereby forming a thin layer of gas between the wire and the tissue. The presence of this film enables the arc to be maintained and the wire to encounter no resistance to its movement. The layers of cells immediately beyond the film-like arc are killed, mainly or entirely by the action of heat. The writer will intentionally use the expression *cauterisation* instead of coagulation, in order to avoid the confusion of electrothermic *cutting* with electrothermic coagulation. The introduction of an arc increases the resistance of the circuit and lowers the intensity of the current in the circuit to a low value. Consequently the tissues, other than those in close vicinity to the arc, are not made hot enough to produce any surgical effect. For this reason it is inexact to use an expression such as "diathermic electrosection." While it is producing an arc a cutting current is not a "diathermic current."

# CHAPTER XXXII

# APPARATUS REQUIRED FOR THE DIFFERENT FORMS OF SURGICAL ELECTROTHERMIC TREATMENT

For each form of surgical electrothermic treatment we require a current generator, various electrodes and the necessary connecting cables. The same generator is not suitable, or not equally suitable, for each form of treatment.

## I. ELECTRODESICCATION

Fulguration, which may be called the parent of electrodesiccation, was originally practised with a generator that had some resemblance to the modern diathermic machine, and the body was actually included in the circuit. By this crude method the sparks were too fierce and they caused violent contraction of the muscles. Although a medical diathermic machine is quite satisfactory for the production of desiccating sparks it is necessary to provide certain additional parts in order to reduce the intensity of the sparks. Before describing them and the way in which they are used an account will be given of the sparks that are most suitable for electrodesiccation.

### Sparks Suitable for Desiccating Tissue

For the successful performance of electrodesiccation the thickness and length of the sparks are factors of considerable importance. If they are too thick they will carbonise, or even burn, the tissue after desiccating a thin superficial layer. The carbonisation will quickly take place before an underlying layer of tissue has been desiccated, and if the sparking is continued the tissue under treatment will be carbonised or burnt, rather than desiccated. If, on the other hand, the sparks are too thin, they will fail to desiccate. It is equally important for the length of the sparks to be adjustable between a minimum of about $\frac{1}{16}$ in. and a maximum of ½ in., or even longer, because the depth below the surface to which desiccation can be made to take place depends on the length of the spark. Short sparks will desiccate only to a slight depth.

### How Suitable Sparks are Obtained

There are two methods of obtaining sparks suitable for treatment by electrodesiccation.

In the *first*, the diathermic machine is connected to a condenser couch. A couch of this kind is illustrated in Fig. 74 and described on p. 156. The patient rests on the couch and is connected to one of the terminals of the machine. The other terminal is connected to the metal plate under the couch. The machine is set in operation and adjusted so as to supply current to the patient. If the operator holds a needle electrode in his hand and brings the point close to the patient there will be a passage of sparks between the point of the needle and the skin. These sparks are not as thick as those which would pass if the patient were directly included in the circuit of the diathermic machine without the use of a condenser. This method is most commonly practised in England. It will be called the *English Method*. It is described in more detail later.

The *second* method is practised by American workers. They do not employ a condenser couch. They use a diathermic machine fitted with a resonator that contains very many more turns than the oscillator. The patient is included in a circuit containing the resonator. By reason of the large number of turns in the resonator it is possible to obtain a higher voltage and longer sparks. Not only are they longer, but they are thinner than those that would be obtained if the patient were included in the circuit of the oscillator.

### Generator for Practice of Electrodesiccation by American Method

A diathermic machine of American design, containing a resonator of the kind mentioned above is illustrated in Fig. 107. It is made by the General X-Ray Corporation, of Chicago.

The oscillator, from which a *diathermic* current is derived, is the stout wire coil seen (in part) at the back of the cabinet. Within it lies the resonator. It is a coil wound in a single layer containing many more turns than the oscillator. The individual turns cannot be seen in the figure. The long axes of the two coils are the same. Connected to the left end of the resonator is a milliamperemeter. The needle, however, does not move while the machine is being used for electrodesiccation. In front of the oscillator on the left side is a switch which is opened when it is desired to supply the machine with current from the A.C. main. On the right side is a crank handle for regulating the strength of current supplied to the machine. In the centre is the amperemeter for measuring the strength of the *diathermic* current. In front of it is the spark gap. It contains four spaces for the sparks to bridge. The width of each space can separately be regulated by turning the appropriate handle. The four handles corresponding to the four spaces can be seen in front of the spark gap.

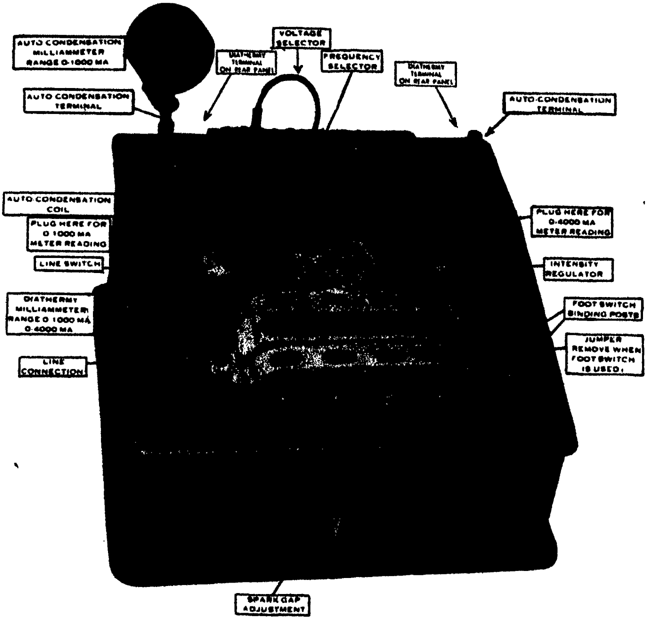
AUTO CONDENSATION MILLIAMMETER RANGE 0-1000 MA
AUTO CONDENSATION TERMINAL
DIATHERMY TERMINAL ON REAR PANEL
VOLTAGE SELECTOR
FREQUENCY SELECTOR
DIATHERMY TERMINAL ON REAR PANEL
AUTO-CONDENSATION TERMINAL
AUTO-CONDENSATION COIL
PLUG HERE FOR 0 1000 MA METER READING
LINE SWITCH
DIATHERMY MILLIAMMETER RANGE 0 1000 MA 0-4000 MA
LINE CONNECTION
PLUG HERE FOR 0-4000 MA METER READING
INTENSITY REGULATOR
FOOT SWITCH BINDING POSTS
JUMPER REMOVE WHEN FOOT SWITCH IS USED.
SPARK GAP ADJUSTMENT

FIG. 107.—Machine constructed to yield a Current for Diathermic Treatment, and another for giving Sparks for Electro-desiccation. (General X-Ray Corporation.)

As is the case with machines of American design the output is adjusted in two ways, both being practised in co-operation. By turning the crank handle (labelled *Intensity Regulator* in Fig. 107) an increasing quantity of current is led into the generator ; in this way the output is adjusted, step by step, within wide limits. By varying the width of the air spaces in the spark gap the output is adjusted *evenly* within narrow limits. The first way corresponds to the coarse adjustment of a microscope, and the second to the fine adjustment.

The actual procedure will be described later.

### Generators for Practice of Electrodesiccation by English Method

Diathermic machines of European make are not all equally suitable for the practice of electrodesiccation by the English method. Those which are designed to produce the highest voltages in the resonating circuit seem to be the most suitable. If the current in this circuit is able to pass, in the form of sparks, across a gap not narrower than ¼ in. the machine will probably be suitable. The best tests, however, are those made when the machine is connected to a condenser couch and tissue experimentally desiccated in the manner described later.

The *active electrode* for use in electrodesiccation is quite simple. A steel rod terminating in a sharp point will do quite well when the English method is practised. It is not insulated—the operator holding it in his hand. For the American method the rod is within an insulating handle. It is provided with a device for attachment of the cable that connects it to the generator.

## II. APPARATUS REQUIRED FOR ELECTROCOAGULATION

### Current Generator

The generators constructed for medical diathermic treatment are suitable for surgical diathermic work as well. The full-size machines described in Chapter VI yield sufficient current, even when they are adjusted to give less than their full output. If the operator does not intend to practise non-surgical diathermic treatment a smaller generator will be satisfactory. Portable machines now are constructed. The smallest portable machines are suitable only for use with active electrodes of the smallest size, *e.g.*, those employed in the coagulation of papillomata of the urinary bladder (by way of the urethra). If these small machines were used with larger electrodes, *e.g.*, a disc measuring 1 cm. in diameter, the current might not attain a density high enough to produce coagulation.

Machines providing one current suitable for electrocoagulation and another suitable for electrosection are now made for surgeons who practise these forms of electrothermic surgery (see Figs. 109, 110).

As far as the coagulating current itself is concerned, it is better for the frequency of its oscillation to be in the neighbourhood of 500,000 cycles per second. Its oscillation need not be fully sustained. Spark-gap generators are quite satisfactory.

### Electrodes

The *indifferent* electrode consists of a sheet of pliable metal, such as lead, $\frac{1}{16}$ in. thick, with a terminal attached for connection to one of the cables from the diathermic machine. It should measure not less than 6 in. by 8 in.

Various forms of *active* electrode are shown in Fig. 108 (Nos. 1 to 17). Nos. 1 to 7 are metal discs : the smallest has a diameter of 6 mm., the largest a diameter of 25 mm. Nos. 8 to 11 terminate in metal balls of various sizes. The largest has a diameter of 6 mm. No. 14 is a single-needle electrode : its length is 30 mm. Nos. 12 and 13 are multiple-needle electrodes. The needles are mounted on discs 8 mm. in diameter and are 12 mm. long in No. 13 and 18 mm. in No. 12. Nos. 15, 16 and 17 are blade electrodes.

Before use the selected electrode is attached to a handle. The latter is made of ebonite, and it may be straight, or curved at one end (Fig. 108, 18 and 19). The ebonite contains a metal core to conduct the current through. Into one end of the metal core the cable from the diathermic machine can be screwed. Into the other (narrow) end the active electrode is screwed. The ebonite projects beyond each end of the core, so that when the cable and electrode

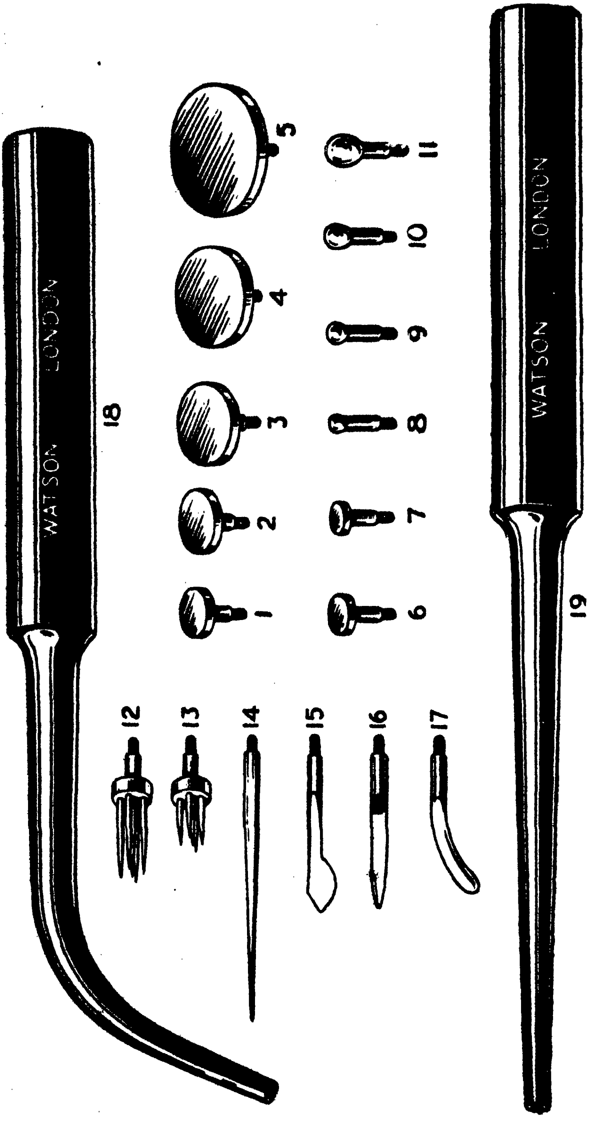

FIG. 108.—Electrodes and Handles for Use in Electrocoagulation.

are in position there is no bare metal near the operator, the only uncovered metal being that which is to make contact with the tissue to be destroyed.

These electrodes and handles are suitable when the part requiring treatment and the process of the operation can be viewed. For the application of diathermy to the post-cricoid region of the pharynx, the œsophagus and the bladder and prostate special electrodes are required. These will be described later.

### III. APPARATUS REQUIRED FOR ELECTROSECTION

#### *Current Generators*

The machines employed in the practice of electrosection generate high-frequency currents on the principles already described (Chapter IV, p. 48 *et seq.*), but their constituent parts are selected or modified so that the machine may provide currents that have the features stated above (p. 373). Some of the machines are of the spark gap type and others contain triode valves. One of each kind is described below.

#### 1. Spark-gap Generator

##### *The G.U. Endo-Diathermy Apparatus*
##### *(Genito-Urinary Manufacturing Co.)*

This machine is illustrated in Fig. 109. It yields two currents, one for electrosection and the other for electrocoagulation. In the interior of the cabinet are a step-up transformer, two condensers joined *in series*, a spark gap, an oscillator and a resonator. There are two spaces in the spark gap between tungsten discs. The width of the gaps is fixed at 0·4 mm. The oscillator and resonator are flat coils.

The machine is connected to the A.C. main. The periodicity of the main current should be 50 cycles per second. The voltage may be either 100, 150, 200 or 240. By opening the large main switch (seen in the figure on the right side of the ebonite control panel) the machine is set in operation. The electrodes are connected by cables to the two terminals shown on the left side of the control panel. By turning the disc (seen just behind the main switch) the operator can direct either the cutting or the coagulating current to the electrodes. The frequency of the cutting current is 6,000,000 cycles per second; that of the coagulating current is 3,500,000 cycles per second. The change in the frequency is effected by short-circuiting one of the condensers. When the above-mentioned disc is in the position marked " cutting " one condenser alone is in the oscillating circuit. When it is moved to the position marked " diathermy " both condensers are in the circuit. The introduction of the additional capacity has the effect of lowering the frequency of the oscillation. The intensity of either current can be adjusted between zero and maximum by rotating the ebonite disc (seen in the figure on the left side of the main switch). A pointer moves over a scale when the disc is rotated. The scale is empirically graduated from zero to 10. When the pointer is at zero the oscillator and resonator are uncoupled and the electrodes receive no current. When the pointer is at 10 the coils are closely coupled and the electrodes receive maximum current.

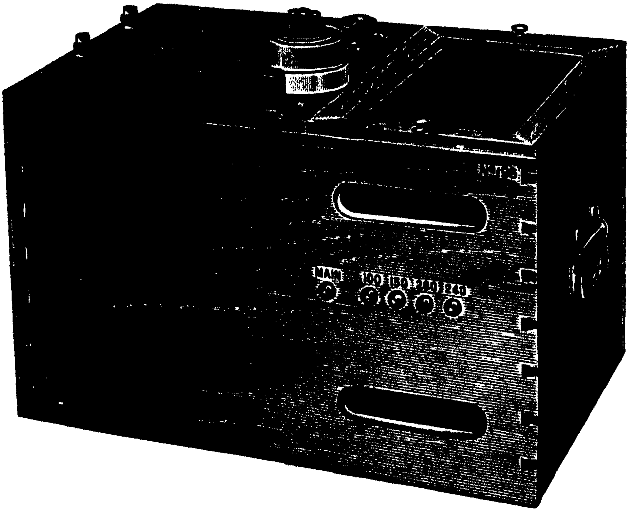

FIG. 109.—Spark-gap Generator that yields a Coagulating and a Cutting Current. (The G.U. Endo-Diathermy Apparatus.)

An arc suitable for cutting skin is obtained when the pointer is over one of the lower divisions of the scale. Larger arcs for cutting fat, muscle or glandular tissue are obtained when the pointer is over higher divisions of the scale.

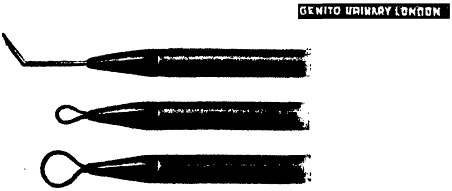

FIG. 110.—Electrodes for Use in Electrosection.

The machine illustrated in Fig. 109 weighs 82 lbs. Its dimensions are 20 in. by 13 in. by 13 in. It is popular among London surgeons. In its original form it was introduced in 1925. Some of the cutting electrodes used with the machine are illustrated in Fig. 110.

## 2. Valve Generator

The *chirotherm* (Fig. 111) is an example of a cutting-current generator of the valve type. This machine provides not only a coagulating current, but also others that produce arcs for cutting different kinds of tissue. Three controlling handles can be seen on the panel. The centre one can be placed in three positions. In one position the machine yields a current suitable for cutting skin. In a second position the current supplied is suitable for cutting other kinds of tissue. In the third position the machine yields a coagulating current. By means of the control handle on the left side of the machine the intensity of each current

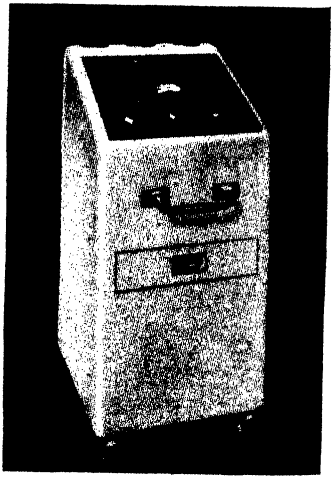

FIG. 111.—The "Chirotherm" Generator, Constructed to Yield a Coagulating and a Cutting Current.

can be finely adjusted. The control handle on the right side enables the current supplied to the filament of the valve to be adjusted to the correct intensity. This intensity is always maintained at the same value. When the needle of the amperemeter (shown at the centre of the control panel) reaches a red mark on the scale the current that heats the valve filament will have attained the correct value.

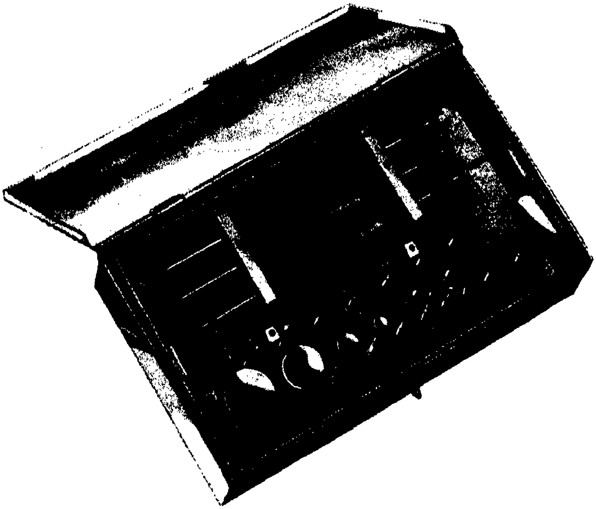

FIG. 112.—Active Electrodes for Use with "Chirotherm" for Electrocoagulation and Electrosection.

In the chirotherm the primary coil of the transformer is connected to an A.C. main. The secondary coil steps the voltage up to 4,000. The current which it yields is rendered unidirectional by means of a rectifier, and nearly constant by means of inductances. This current charges the condenser, and as it is undirectional and almost constant the oscillations of the currents yielded by the machine are sustained and undamped. Their frequency is one million cycles per second.

Electrodes for use with the *chirotherm* are illustrated in Fig. 112. Some are for electrosection and others for electrocoagulation.

## CHAPTER XXXIII

# EXPERIMENTAL TRIAL OF THE ELECTROTHERMIC METHODS ON RAW MEAT

ALTHOUGH experiments on meat are not the same as operations on the living body they should nevertheless be performed because they enable the operator better to appreciate the nature of the electrothermic methods and what they do and learn the effects of changing the strength of the current, the type of active electrode, etc.

### 1. Experimental Electrodesiccation

#### (a) *The English Method*

In order that the conditions of the circuit may closely resemble those that exist when patients are subjected to the treatment a living subject should sit on the couch and hold a metal rod in his hands. The meat may be supported by the rod or placed on the back of his hand. The rod is connected to one of the terminals of the machine, and the metal plate under the couch to the other terminal. The switch of the machine is opened and the coupling handle adjusted so that a small amount of current oscillates in the patient's circuit. The operator grasps the metal electrode in his hand and brings the point close to the meat. The point will be almost in contact with the meat before sparks pass. The length of the sparks can progressively be increased by moving the coupling handle and allowing more and more current to oscillate in the patient's circuit. The sparks pass because there is a difference of potential between the conductor on the couch (*i.e.*, the patient and the rod in his hands) and the electrode held by the operator. This electrode is at the earth's potential, viz., zero. A better connection between this electrode and the earth can be made by means of a length of wire joining it to a water pipe, radiator or any other " earthed " object. By making a connection of this kind the sparks, however, may become too thick.

The sparks should be quite short, to begin with, and they should be directed over quite a small area of the meat. The following events will be observed. The part on which the sparks fall will quickly be rendered pale. A very thin superficial layer will be dried. As the sparks continue to pass, the dried layer will gradually grow thicker and begin to shrink owing to its deprivation of moisture. After a time the sparks will cease to pass because dried tissue is a non-conductor. If, however, the sparks are made longer they will perforate the dried layer and desiccate an underlying layer. Eventually the longest sparks will be unable to pass through the increased thickness of dried tissue, even if the needle is placed *in contact* with the surface. If, however, the point is passed into the dried tissue it will be able to desiccate a little more deeply. During the experiment an escape of steam may be seen, owing to the boiling of the tissue juices by the heat of the sparks. The portion of the tissue which has been subjected to the action of the sparks will be seen to be shrunken and hard. The superficial part will be dark brown or grey in appearance because it has been subjected to the action of the sparks for the longest time.

The maximum length of spark obtained in the way described depends on the design of the generator. When some generators are used it is possible only to obtain very short sparks that desiccate only to a slight distance below the surface. They can be made a little longer if the operator sits on the couch beside the patient or if he earths the active electrode. By either of these methods, however, the sparks may be rendered too thick. If the sparks are too thick they will quickly desiccate a superficial layer of tissue and carbonise it before there is time for the desiccation to proceed more deeply.

### (*b*) *Experimental Electrodesiccation by the American Method*

A subject, seated on a chair or reclining on an ordinary couch, holds a portion of meat in his hand. The active electrode is connected to one of the terminals of the resonator by an insulated cable. The other terminal is earthed. Three of the spaces of the spark gap are closed and the fourth is opened just a trifle. The crank handle is placed in the position that enables the minimum amount of current to be received by the machine. The main switch is now opened. The operator, holding the insulating handle of the active electrode, brings the point close to the meat. Only very short sparks pass. Gradual increase of the width of the space in the spark gap causes a progressive increase of the length of the sparks.

The length and also the thickness of the sparks can be adjusted within wide limits by varying the width of the spark gap and the quantity of current received by the machine. The sparks can also be made thinner by disconnecting the resonator from the earth. In the machine illustrated in Fig. 107 it is possible to make further adjustments of the length and thickness of the sparks by means of the " volt selector." This is a device which enables the entire length of the oscillator, or as many turns as desired, to be included in the oscillating circuit. When fewer turns are included a lower voltage will be reached in the oscillator and, consequently, in the resonator.

The action of the sparks on the meat is the same as that already described. Desiccation to a greater depth can be procured because longer sparks can be obtained by the American method. The desiccating action of sparks can also be demonstrated on soap. The writer was shown an interesting experiment in Philadelphia by the late W. L. Clark, the originator of the American method. He placed his visiting card on a cake of soap. The sparks perforated the card without burning it. The portion of soap on which they fell was rendered quite dry. It was easily separated by the point of a penknife.

## 2. Experimental Electrocoagulation of Meat

Two electrodes are needed. One is the active electrode and the other the indifferent electrode. The object of the last-mentioned is to complete the circuit.[1]

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[1] In the practice of electrodesiccation there is no need to place an indifferent electrode *on* the body. In the English method the metal plate under the couch acts as an electrode of this kind. In the American method the couch or chair and the objects in the room play the part of an indifferent electrode.

A fairly large mass of beef should be obtained and placed on a metal plate measuring 6 in. by 8 in. The plate should be connected by a cable to one of the terminals of the diathermic machine. It constitutes the *indifferent* electrode. An *active* electrode should be attached to the ebonite handle and placed in contact with the beef. The latter should be 3 or 4 in. thick. Thin pieces are unsuitable.

### *Coagulation with Disc or Ball Electrodes*

A disc 6 mm. in diameter should be used as the active electrode for the first experiment. The current is now started and gradually increased. The following events take place.

The tissue in contact with the disc becomes gradually hotter until it coagulates. Coagulation begins *under the edge* of the disc. It spreads to the centre of the disc and below the surface. It then extends beyond the edge of the disc and now comes into view. A hissing sound is now heard. At first faint, it grows louder and steam begins to escape from under the disc. The fluid in the tissue under the disc now passes into a state of violent ebullition. The noise increases and becomes crackling in character owing to the appearance of sparks. The sparks pass from the edge of the disc over the coagulated tissue around the edge of the metal to the uncoagulated tissue beyond. If the current is continued or further increased the sparks increase in length and whiten the surface of the tissue for an increasing distance around the disc.

The reason for the appearance of the sparks is the *drying* of the coagulated tissue in contact with the disc. The tissue in this situation is deprived of all its fluid ; it has, in fact, been " boiled dry." The dried tissue is a non-conductor, and the current passes in the form of sparks which dart from the edge of the disc to better conducting tissues beyond.

When this " insulating button " of dried tissue has formed, it prevents the current coagulating any more tissue. The sparks that pass from the edges of the disc will fulgurate (desiccate) the tissue on which they fall. In other words, electrocoagulation will be replaced by electrodesiccation. But only a thin superficial layer of tissue around the disc will be desiccated.

If the current is stopped when sparks first appear and the tissue cut across vertically through the centre of the coagulated mass, the appearance will be similar to that shown in Fig. 113 at *a*. This shows that the coagulation had spread *below* the disc for about 6 mm., a distance equal to the diameter of the disc. It had spread *around* the disc for 3 mm. beyond the edge. The mass of coagulated tissue was rather less than a hemisphere in shape.

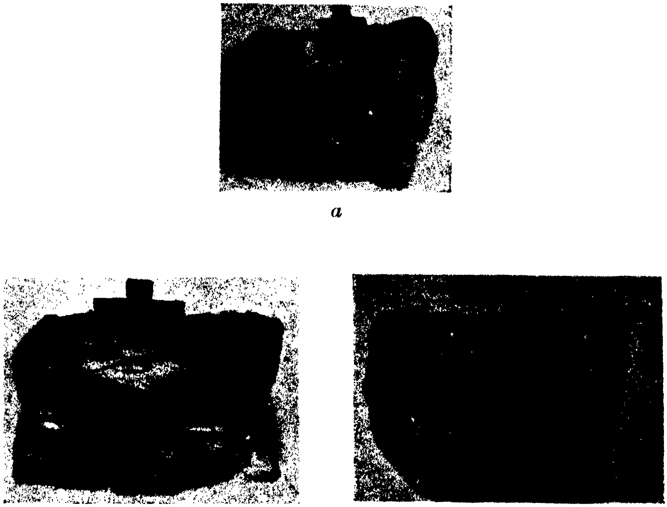
*a*

Fig. 113.—Amounts of Tissue Coagulated by Diathermic Current when Disc-Electrodes of Different Size are used. Diameter of Disc is 6 mm. at *a*, 10 mm. at *b*, 15 mm. at *c*.

If discs of longer diameter are used and the experiments repeated, the events that occur are similar to those just described. The larger the disc the larger the mass of tissue that is coagulated, and the longer the time expended before sparks appear. In the experiments illustrated in Fig. 113, *b* and *c*, discs of 10 mm. and 15 mm. were used. The current was increased from zero until sparks just appeared. The coagulation spread, in each experiment, to a depth equal (approximately) to the diameter of the disc.

If these experiments are repeated and the current *suddenly* applied at full strength, and not increased gradually from zero, it will be found that the coagulation will not extend to as great a depth. This is especially the case when small discs or large currents are used. The reason for this is the following. The diathermic current does not coagulate the tissue instantaneously ; some of the heat is conducted away (though slowly), and it takes time to elevate the temperature to coagulation point. Now, if the current is suddenly started at the strength at which boiling appears, without gradually increasing it from zero to this strength, the sudden intense heat quickly dries a thin layer of tissue in immediate contact with the active electrode, and sparks appear before sufficient time has elapsed for the temperature of the deeper part to rise to coagulation point.

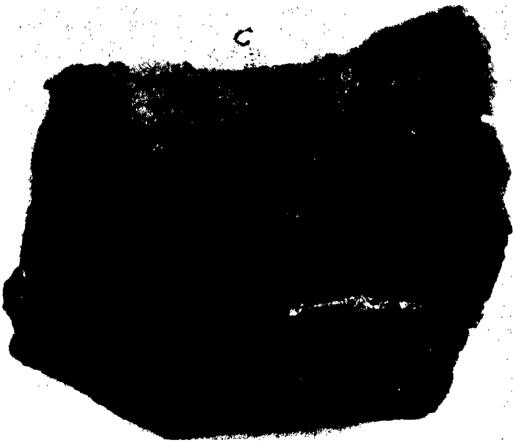

FIG. 114.—Amount of Tissue Coagulated when Diameter of Disc is 20 mm.

If, on the other hand, the experiments are repeated and the current increased *very slowly* from zero it will be found that the coagulation will extend to a depth greater than the diameter of the disc. Very slow increase of the current delays the drying of the tissue in contact with the disc and allows time for the tissue at a greater depth to coagulate.

When discs of larger diameter than 15 mm. are used the current-density has a low value and the tissue in contact is heated slowly. For the reason just given the coagulation is likely to proceed to a depth greater than the diameter of the disc. Fig. 114 shows the amount of tissue coagulated when a disc of 20 mm. in diameter was used. It was not until three and a half minutes had elapsed that vigorous boiling occurred. Coagulation had then extended 25 mm. below the surface, *i.e.*, 5 mm. more than the diameter of the disc.[1]

It may be concluded, then, that the use of large disc electrodes and the very slow increase of current (and heat) does not enable the operator to foretell the depth to which the coagulation will extend. On the other hand, the use of discs not larger than 15 mm. in diameter, and the increase of the current from zero to the value at which the sparks are first seen (a few seconds being occupied in the increase), will cause the coagulation to proceed to a depth equal to the diameter of the electrode.

The reading of the amperemeter gives no information of practical value regarding the extent or depth of coagulation.

### *Coagulation with Needle Electrode*

If a single-needle electrode, like that shown in Fig. 108 (No. 14), is used and thrust into the tissue for, say, 2 cm., the coagulation will commence *at the point* of the needle and spread upwards around its shaft until it reaches the surface of the tissue. By the time it reaches the surface, or a little before, the sound of ebullition will be heard. If, now, the current is stopped and the needle withdrawn, the coagulated mass can be seen by cutting the tissue along the line formerly occupied by the needle. It is cylindrical in form and surrounds the needle like a sheath (Fig. 115, *a* and *b*).

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[1] The tissue in contact with the disc electrode can be prevented from drying by allowing salt solution to drip around the edge of the disc while coagulation is proceeding. If sparks appear they can be quenched and the boiling stopped for a few moments by allowing a drop of the solution to fall. Boiling and sparking soon recur, but can be again stopped in the same way. In the deeper parts, however, the coagulation continues to spread, and it reaches a considerable distance. Fig. 117 shows the large mass of tissue that was coagulated when the machine was giving its maximum current and drying was prevented by salt solution. The disc electrode measured only 6 mm. in diameter.

If the current is allowed to flow for a longer time before withdrawing the needle there will be scarcely any further spread of coagulation beyond the point or sides of the needle. The reason for this is the drying of the tissue in contact with the needle and its conversion into an insulating sheath. Just as the coagulation starts at the point and proceeds up the shaft to the surface of the tissue, the drying begins in the same region and follows the same direction.

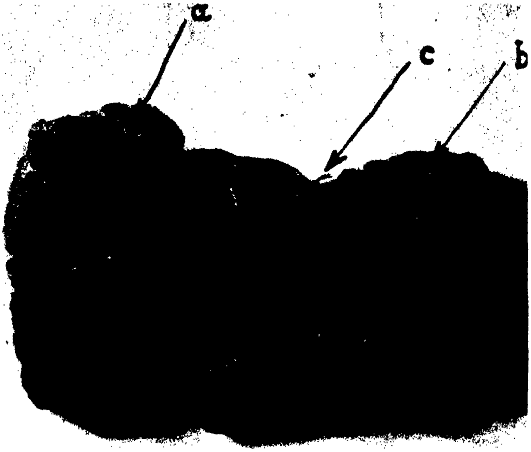

FIG. 115.—Tissue Coagulated when Needle Electrode is Used.

If the needle remains in position until the tissue in contact is dry, and then withdrawn, it will bring with it portions of tissue tightly adherent to its surface. If, however, it is withdrawn at the moment when the tissue around is coagulated and before it is dried, it will come away clean and bring no tissue with it.

It has already been shown that the *rate of increase* of the current influences the extent of spread of coagulation when disc electrodes are used. The same is true when single-needle electrodes are used, but the influence of the rate of increase is very much less. The area of contact of tissue and metal is very small and the current, in consequence, is highly "concentrated." Coagulation and drying are quick. In Fig. 115 (*b*) the coagulation extended 1 mm. around the needle; the current was applied suddenly at full strength. In Fig. 115 (*a*) the current was started at zero and a few seconds were occupied before coagulation reached the surface; coagulation spread for 2 mm. around the needle. In Fig. 116 the coagulation had spread 4 mm. around; the current was very slowly increased, three minutes being occupied before it reached its maximum.

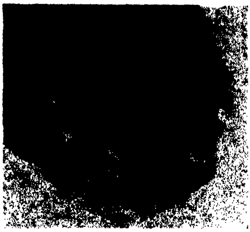
FIG. 116.—Tissue Coagulated by Current of Long Duration. (Needle Electrode.)

If the needle is allowed to remain in position and the current maintained or increased for a time after the tissue in contact with the metal has dried, sparks will pass from the point and sides of the needle through the dried sheath, and slowly char it. At the same time the tissue immediately beyond will be coagulated to a slight additional distance. This, in its turn, will be dried and charred. In this way it is possible, by means of the needle electrode, to burn out a cavity. But even if this is done the coagulation will not extend for more than a slight distance into the tissue lining the cavity. This is illustrated in Fig. 115 (*c*); a cavity has been produced, the tissue having been burnt away by the long-continued passage of sparks. After a time the needle was moved around the wall of the cavity. Coagulation did not extend for more than 3 mm., however, into the tissue lining the wall.

### *Blade Electrode*

When a knife electrode like that illustrated in Fig. 108, No. 16, is thrust into the meat and the current gradually increased, the coagulation will begin around the point and then spread upwards around the blade to the surface.

FIG. 117.—Large Mass of Tissue Coagulated with Small Disc Electrode (marked *end-piece*) when Sparks are Quenched.

The electrode should now be moved slowly forwards in the direction of the cutting edge—the current passing all the time. In this way an incision can be made and a portion of the meat can be excised. The blade should be moved slowly enough to enable the edge to cut only coagulated tissue. If the experiment is successful the remaining cavity will be left with a coagulated wall.

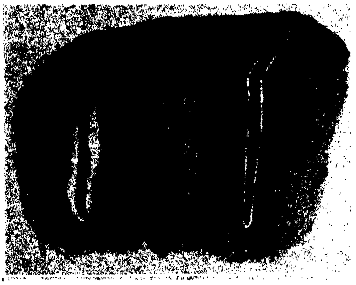

FIG. 118.—Block of Tissue after Incisions by Electrothermic Methods. *a*, Incision by Scalpel carrying a Diathermic (Coagulating) Current. *b* and *c*, Incisions by Fine Wire carrying a Cutting Current Producing an Arc (Electrosection).

The appearance of meat after synchronous coagulation and cutting is illustrated in Fig. 118, *a*. The active electrode was a blade 2 mm. wide.

When *living* tissue is killed by means of the diathermic current and the disc, ball or needle electrodes, it separates from the body by the process of sloughing. The object of using the blade electrode is to remove the abnormal part at the time of the operation and leave less tissue behind to separate by sloughing.

### *Snare Electrode*

A flexible wire loop mounted on the end of a suitable holder (Fig. 155, p. 499) can be used as an active electrode when it is desired to coagulate the base of a pedunculated growth and remove it at the same time. Its action may be demonstrated by passing the loop around a projecting portion of meat and starting the current when the wire is grasping the tissue. The tissue in contact with the wire whitens from coagulation. The loop now is slowly tightened while the current continues to pass. The wire gradually makes its way through coagulated tissue until the projecting portion of meat is nipped off. The divided surfaces will be seen to be coagulated.

### *Circumvallation*

It has already been observed that coagulation does not extend for more than a slight distance around the shaft of a needle electrode. By repeated insertion of the needle into adjacent parts of the tissue—the directions of insertion being parallel on each occasion—and coagulation of the tissue around, it is possible to produce a wall of coagulated tissue. If the coagulation extends for 2 mm. around the needle it should be inserted successively at points 4 mm. from each other in order to secure an uninterrupted wall of coagulated tissue. The wall can be made cylindrical if desired. The length of cylinder will correspond to the length of insertion of the needle. It is also possible to make the wall the shape of a hollow cone, its rim being on the surface of the tissue, and its apex at the desired depth below. This can be done by inserting the needle obliquely at different points along the circumference of a circle (which will be the rim of the cone) to a common point (which will be the apex of the cone). When this is done the tissue within the wall of coagulation will be shut off from that outside. In the *living* body the blood and lymph vessels in the wall would be sealed.

The name "circumvallation" was given by Howard Kelly to the coagulation of the *healthy tissue around* an abnormal part. The object of circumvallation is to provide an isolating wall or rampart around a malignant growth, and minimise or prevent the risk of artificial metastasis when the growth itself is removed or a portion excised for histological examination. In itself, circumvallation is not sufficient for the treatment of malignant disease.

### 3. Experimental Electrosection of Meat

An active and an indifferent electrode are required. The active electrode should be a fine tungsten wire, no more than 0·008 in. in thickness. It is attached to an insulating handle. A length of insulated cable connects the electrode to one of the terminals of the cutting-current generator. The indifferent electrode is a sheet of metal. It is connected to the other terminal. A block of raw meat is placed on this electrode. Alternatively, it may be placed on the hand of a living subject. By his other hand he grasps a rod electrode which is connected to the disengaged terminal of the machine.

The machine is set in operation and adjusted to give a current suitable for cutting tissue other than skin. The end of the wire will be almost in contact with the meat before a current passes, because the voltage is low. A minute arc appears in the intervening air-space. When the wire is thrust into the tissue it enters as easily as if it were passing into water. When it is drawn across the meat, as in making an incision, it encounters no resistance to its passage. The tissue seems to separate of its own accord on each side of the advancing wire. If, now, the current is stopped and the divided surfaces examined they will present a pale appearance as if they had been coagulated. The depth to which the arc has cauterised them is slight. On the surface of the meat it can be seen as two white lines, one on each side of the line of incision (see Fig. 118, *b*, *c*). They can more distinctly be seen by bringing the divided surfaces into apposition.

Further experiments should now be made on the meat in order to learn the various factors that influence the depth to which the arc cauterises the divided surfaces.

The *first* factor is the intensity of the current that produces the arc. Currents of low intensity produce small arcs and *vice versâ*. (The expressions minute arc, large arc, etc., are used colloquially for the sake of convenience. In actual practice the difference in size between one arc and another cannot be judged by inspection.) The generator should be adjusted so as to give a small current. On moving the active electrode through the meat it will be found that the divided surfaces will be cauterised to an extremely slight depth. Now adjust the machine so as to yield its maximum output and make another incision of the meat. The "large" arc will proceed in a noisier manner and cauterise the divided surfaces to a much greater depth.

The *second* factor that influences the depth of cauterisation is the speed of movement of the electrode. Adjust the machine so that it can yield a medium output. Move the electrode quite slowly through the meat and note the depth of cauterisation. Then move it very quickly through another portion of the meat. It will be observed that the depth of cauterisation is much less with the quick movement.

The *third* factor is the thickness of the wire electrode. The use of a thicker wire will enable more current to pass. Consequently the arc will be larger and will cauterise to a greater depth than the smaller arc around a thinner wire.

The *fourth* factor is the depth of insertion of the wire. Insert it only to a slight distance and note that the depth of cauterisation is greater than will afterwards be found to be the case when the experiment is repeated and the wire introduced to a greater distance. The output of the machine and the rate of movement of the wire must be the same, of course, in each experiment.

The *fifth* factor is a very important one. It is the nature of the tissue which is being incised. The same arc will not cauterise other tissues to the same depth as meat (muscle), even if the same electrode is inserted to the same depth and moved at the same speed. The experiments just described should be now repeated on fat instead of muscle.

It will be observed that the arc proceeds more quietly through fat than through muscle or fibrous tissue. The fat in contact with the arc is melted. A " larger " arc is required in order to enable the wire to pass through fatty tissue with the same ease as through muscle, and it cauterises it to a greater depth. The actual depth is influenced in the same way as in muscle by varying the speed of movement, the depth of insertion and the thickness of the wire electrode.

Experiments of this kind on various tissues will enable the operator to gain some preliminary knowledge of the factors that decide the depth to which the divided surfaces are cauterised before learning the practice of electrosection on the living body. The matter of the depth of cauterisation is not merely of academic interest. The question of hæmostasis and the occurrence of primary union are decided by it.

# CHAPTER XXXIV

## THE ELECTROTHERMIC METHODS AND *LIVING* TISSUE

HAVING studied the action of desiccating sparks, coagulating currents and cutting arcs on *dead* tissue it is necessary now to learn their action on *living* tissue. The tissues of the living body can be desiccated, coagulated or cut in the same manner as raw meat, but the existence of the circulation is a disturbing factor which was not encountered in dead tissue. Its influence must be considered.

### 1. Electrodesiccation of *Living* Tissue

Desiccating sparks not only dry the tissue cells but they also exert action on the walls of the vessels and the fluids within them. Instantaneous constriction occurs. The moment the sparks fall on the epidermis the skin becomes dead-white. At the same time the more superficial capillaries and their contents are dried. While the sparks continue to fall the same effect is brought about in the microscopic arterioles and venules. The actual depth below the surface to which it is possible to desiccate the vessel walls and their contents—thereby obliterating them—is influenced by the length of the sparks and the position of the needle electrode. But there will always be vessels in the situation that marks the boundary between unharmed tissue and desiccated tissue ; in this region there will be vessels with desiccated walls and non-desiccated contents, or even vessels with walls that are merely constricted without damage. Should the overlying and completely desiccated tissue be intentionally removed, there will be an escape of blood from the underlying vessels. Further reference to this matter will be made when the operation of electrodesiccation is described.

The circulation also has the effect of limiting the depth to which the sparks can desiccate tissue. At a depth where the heat would be just sufficient to desiccate tissue (if it were bloodless) the heat-convecting action of the circulation would just prevent desiccation of tissue that had its blood supply. It is in highly vascular tissue that this heat-convecting action of the circulation hampers the desiccating action of sparks and hinders its effect on the deeper tissues.

### 2. Electrocoagulation of *Living* Tissue

#### *With Disc or Ball Electrodes*

When the living tissues are coagulated the events which occur are similar to those already described. The tissues around and under the active electrode acquire pallor from coagulation. Steam escapes and boiling occurs. Finally, the tissue in contact with the electrode dries and sparks make their appearance. The distance below and around the electrode to which the coagulation extends is influenced by the size of the electrode, as in excised tissue. It is also influenced by two additional factors, viz., the movement of the blood, and the degree of moisture of the tissue.

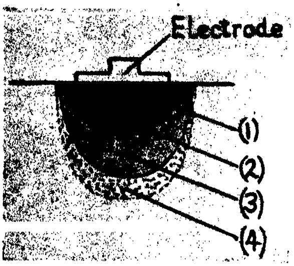

FIG. 119.—Schematic Repre-

The blood removes, by convection, some of the heat generated by the current. This has the effect of preventing coagulation in the region where the heat would, in non-vascular tissue, be just sufficient to cause it. For this reason the coagulation does not extend so far below or around the electrode in living tissues. On the other hand, it must be remembered that cells can be deprived of their vitality and life by heating them to a temperature insufficient to coagulate their protoplasm. Further, the lethal temperature for malignant cells is lower than that for normal cells. It must be concluded, therefore, that tissue is killed for a little distance beyond that to which actual coagulation proceeds. Under the electrode (after coagulation is complete and sparks appear) the killed tissue may be regarded as divisible into four zones or strata (see Fig. 119). In contact with the electrode the tissue is coagulated and then dried. This is the "insulating button." Under it the tissue is coagulated but not dried: the cells are killed and the vessels and their contents coagulated.

In the next stratum the cells and the vessel walls are coagulated but not the blood. The latter moves through the heated part and passes out of it before sufficient time has elapsed for it to coagulate. The temperature in this stratum is only high enough to coagulate the non-moving parts. Beyond this stratum the temperature, while insufficient to coagulate, is high enough to exert a lethal action on malignant tissue.

If the disc electrode is placed in contact with skin the coagulation will not proceed more than a slight distance below the surface, because the epidermis, a relatively dry tissue, is soon rendered completely dry and non-conducting. The same is true of bone. The periosteum dries very quickly and sparks appear almost at once.

These facts render it difficult to judge with accuracy the depth to which the tissues will be killed when disc electrodes are used. As an approximate guide, however, it may be taken that the depth of destruction, in the case of moist soft vascular tissue, is equal to the diameter of the disc when the current is increased until sparks appear.

### *With Knife Electrode*

When living tissue is simultaneously coagulated and cut by means of a knife electrode the vessels are cut as well as the tissue around them. If the blood is not coagulated by the heat before the vessels are severed it will escape. Loss of blood is a serious disadvantage. It obscures the field of operation and is difficult to stop, because the heat generated by the current lessens the viscosity of the blood, accelerates its flow and increases its supply. But there is a more serious risk when malignant tissue is being treated. If bleeding occurs and the cells have not been destroyed there is the likelihood of producing metastasis.

It requires considerable practice to perform this combined operation without loss of blood. It is in the region of the point of the blade that capillaries and lymphatics, or larger vessels, are liable to be cut before their contents are coagulated. The operator cannot see the extent of the coagulation except on the surface, and it is easy, when moving the blade forwards, to press its point into uncoagulated tissue.

### *Circumvallation in Living Tissue*

It has already been stated that circumvallation is practised for the purpose of surrounding a malignant growth with a barrier of coagulated tissue. The procedure just described is really a combination of circumvallation and excision. The part to be removed is surrounded by a wall of coagulated tissue and the wall is divided into two layers as fast as it is formed. On account of the risk of bleeding when this procedure is practised, it is better to perform the operation in two stages, first procuring the circumvallation *by means of a needle electrode*, and then employing the blade electrode and diathermic current for the removal of the part within the coagulated wall. But even with the additional protection afforded by circumvallation it is not easy to prevent bleeding because the point of the knife may unintentionally be passed through the coagulated wall. It is safer, therefore, to employ the cutting arc for the purpose of removing, by electrosection, the tissue enclosed within the coagulated wall.

### *With Needle Electrode*

When a single-needle is used as an active electrode the coagulation commences around the point of the needle and spreads upwards around the shaft until it reaches the surface. The distance to which it spreads beyond the electrode is rather less than is the case with non-living tissue. When the coagulation has spread, say, *one* millimetre around the shaft at the surface (where it is visible to the eye) it is not likely to have spread more than *two*, or, at the most, *three* millimetres below or around the point of the needle. It is evident, therefore, that the depth to which the living tissues are destroyed by the diathermy current is much more under the control of the operator when a needle electrode is used. Whether the tissue is moist or relatively dry, and whether it is highly vascular or otherwise, the depth of destruction is determined by the depth of insertion of the needle.

### 3. Electrosection of *Living* Tissue

The tissues of the *living* body can be cut with the same facility as dead tissues and the divided surfaces are cauterised in the same way. In its passage the arc severs all the vessels on its path and cauterises their cut edges. There is no escape of blood from those vessels that are microscopic in size because the arc is able to coagulate the minute amounts of blood just within their severed ends, and the pressure within them is insufficient to dislodge the coagulated contents. Theoretically, the smallest arc capable of dividing tissue would seal only the capillaries, whereas one which was a little larger would seal also the microscopic arterioles and venules. A still larger arc might seal the just visible arterioles. But although the use of large arcs will prevent bleeding from the less minute vessels they will have the disadvantage of cauterising the divided surfaces to a depth that may be too great to enable them to heal by first intention after they are sutured together.

Even if the generator is adjusted to yield its *maximum* output there will be an escape of blood from the larger vessels after the arc has severed them. A quick method of sealing the divided ends will be described later.

# CHAPTER XXXV

## ADVANTAGES AND LIMITATIONS OF THE ELECTROTHERMIC METHODS

THE use of electrodesiccation or electrocoagulation for killing abnormal or unnecessary tissue, or the employment of electrosection for removing it, have certain advantages in comparison with the use of caustics or the actual cautery or the scalpel. Likewise, they have their limitations. The advantages and limitations of each electrothermic method will be considered in turn.

### 1. Electrodesiccation

#### *Advantages*

It is necessary to state the advantages that treatment by electrodesiccation has to offer in return for its apparent complexity, not to say the experience needed for its successful practice and the cost of the apparatus. Probably the greatest advantage is the soft, non-contracting scar tissue that replaces the part which has been treated. This makes the method particularly valuable in the treatment of growths of the vocal cords, and in cases where good cosmetic results are essential. The writer has never seen a scar contract or adhere to underlying parts after electrodesiccation, even if years have elapsed since the treatment. Two of his cases have been under observation during periods of fifteen and sixteen years, respectively. Repetition of the treatment, in cases where it is necessary, does not make the scar hard. Another advantage that electrodesiccation has to offer is the slightness of the reaction after the treatment. Desiccated tissue does not seem to irritate the adjacent parts. Usually the patient has little or no pain or discomfort after the treatment. Electrodesiccation can be confined, when necessary, to minute amounts of tissue. For this reason it can safely be utilised in the treatment of growths of the eyelid, sclerotic and vocal cords. Electrodesiccation is a quick mode of treatment and does not cause any loss of blood.

### *Limitations*

The use of electrodesiccation has its limitations. Only those parts that are accessible, *i.e.*, within reach of the active electrode, can be treated by this method. The pathological tissue must be in full view of the operator, with or without the help of a viewing instrument, so as to enable him to see it while the sparks are falling on it. For these reasons it is possible to treat abnormal tissue in the following regions only, viz., the skin, and the mucous membranes of the mouth, throat, portions of the nasal cavity, external auditory meatus, sclerotic, cornea, rectum, vagina and vaginal portions of the cervix uteri. If the abnormal part is covered by skin or mucous membrane it cannot be reached without desiccating the healthy overlying tissue. It is unsuitable for the treatment of large masses of tissue or those that extend more than about 1 cm. below the surface.

## Examples that Illustrate the Advantages Offered by Electrodesiccation

A few words on some of the writer's cases will show the usefulness of electrodesiccation in procuring soft non-contracting scars, a painless or almost painless reaction, and good cosmetic results.

The long-lasting softness and non-shrinking character of the scars is illustrated in the 3 cases which have been kept under observation for the greatest length of time, viz., sixteen, fifteen and ten years, respectively. In the first patient there was a patch of lupus vulgaris, ¼ in. in diameter, on the shoulder. It was treated when she was 15. She is now 31. The scar is still soft and smooth, and there is no sign of lupus. The second patient had a pigmented mole on the abdomen measuring about ½ in. by ½ in., and projecting about ¼ in. from the surface. It caused some alarm because it occasionally bled. There was no evidence of malignancy. It was treated by electrodesiccation in 1921. At the present time there is a smooth soft scar. The third patient, a man who now is 46, had a number of nodules of lupus vulgaris in the skin of his left shoulder and upper arm. Some had not long been in existence when the writer first saw him in 1926. These were treated by electrodesiccation. To-day the scars are soft and they are not shrunken or depressed. Some other nodules which were of much longer duration required repeated treatment over long periods of time. In spite of this, however, the scars did not grow hard.

The slight degree, or even absence, of pain or irritation after electrodesiccation is illustrated by a case of papilloma of the tongue in a lady of 60, treated on January 7th, 1935. The patient came to report on February 13th. She said that she had had a feeling of swelling on the day of the operation and a certain degree of irritation during the following week, but no pain. Close scrutiny was needed to detect the scar, denoting the site of the operation.

Some idea of the cosmetic results can be obtained by inspecting Figs. 133–142, pp. 455–460.

## 2. Electrocoagulation

### *Advantages of the Method*

When abnormal tissue is coagulated by the diathermic current there is no disturbance of its anatomical continuity. Not only is it killed but its small blood vessels and lymphatics are sealed. These advantages are important when malignant growths are subjected to the treatment. The patient suffers little or no shock, even after the coagulation of large masses of tissue; and if he is warded his stay in bed need not be long. Pain, if present, is almost always relieved. Complications are rare and most of them can be avoided.

If the current is employed to coagulate the healthy tissue around a malignant mass a portion of the growth can be removed without risk for histological examination, and when the remainder is removed the danger of artificial dissemination is reduced to a minimum.

The main disadvantage of electrocoagulation is the necessity for the separation of the killed tissue in the form of a slough. Healing, therefore, can occur only by second intention. During the process of healing there is an open sore. The scar tissue that fills the cavity does not contract, nor does it form adhesions with tissues in contact.

### *Limitations*

The use of electrocoagulation has its limitations like electrodesiccation. The pathological tissue to be treated must be in a situation where it can be reached by the active electrode. As this electrode is placed in direct contact with the tissue and not at a little distance—as is the case with electrodesiccation—it is possible to practise the treatment in some regions which are inaccessible for the practice of the last-mentioned method. Growths and infective granulomata of the skin, and the mucous membranes of the mouth, tongue, pharynx, larynx, œsophagus, rectum, bladder, posterior portion of the urethra, adjacent parts of the prostate, vagina and vaginal portion of the cervix uteri are accessible.

### *Contrast between Coagulation by Diathermy and Cauterisation with Hot Metal*

When a hot metal object, *e.g.*, the burner of a Paquelin cautery, is thrust into the body the destructive action of the heat does not spread more than a slight distance beyond the hot metal, even if the tissue in contact with it is carbonised or actually reduced to ash. Fig. 120 (*a*) shows the limited extent of the cauterisation produced around a Paquelin burner. The burner, which was 0·5 cm. broad, was heated and thrust 2·5 cm. into a piece of raw meat. The heating was kept up for twenty seconds. The tissue that was in contact with the burner was charred, while coagulation extended inwards for 2 mm. only. The same burner was then introduced—cold—for the same distance into another piece of meat and used as an electrode to lead the diathermy current into the tissue. Fig. 120 (*b*) shows that coagulation has spread much farther around, the distance being about 1·5 cm. below the end of the electrode, and about 1 cm. to each side. The cauterisation by the red hot platinum had burnt out a hole with charred blackened walls. The size of the hole was larger than the burner, so that the latter could be easily lifted out. When the diathermic current was used the tissue round the metal dried and adhered to the electrode. There was no charring, although the photograph gives this appearance.

In diathermic coagulation the electrode is cold when it is placed on or in the tissues, and remains cold until it is heated from contact with the electrically-heated tissues.

In the other methods of cauterisation by heat the cauterising metal is red hot before use, but cools when introduced into the tissues. In these methods the heat is introduced from without and spreads within by conduction. In diathermy the heat is generated within the tissues. The former methods produce cauterisation by "epithermy," the latter produces coagulation by diathermy.

Coagulation by the diathermic current is also quite distinct from the destruction produced by electrochemical methods. In the latter the galvanic current is used, and the destruction is produced by the caustic chemical bodies which accumulate around the electrodes. When describing the properties of the diathermic current it was mentioned that this current produced no chemical change in the body and no direct stimulation of the excitable tissues. A very much larger current can, therefore, be used for diathermic coagulation than for electrochemical cauterisation, with a corresponding increase in the amount of tissue that can be destroyed.

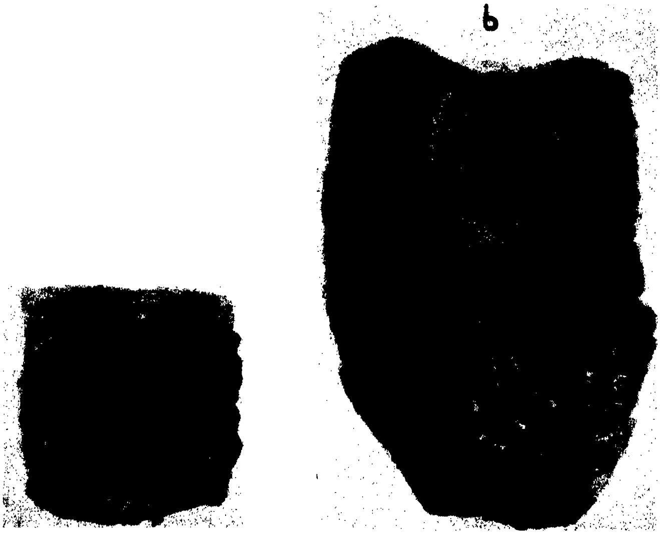

Fig. 120.—*a*, Tissue subjected to Burning Action of Paquelin's Cautery. *b*. Tissue subjected to Coagulating Action of Diathermic Current.

### 3. Electrosection

The most obvious advantage is the sealing of the microscopic blood vessels at the time when they are severed. The microscopic lymph vessels also are sealed. It is likely, too, that the larger lymphatic channels are sealed at the same time. As the pressure of the lymph within them is very low it is probable that their walls are brought into apposition when the arc passes across them. If this is the case their walls will be sealed together and their channels occluded. The closure of the divided ends of the vessels will minimise or prevent the mechanical dissemination of malignant cells or organisms that may be infecting the tissue, especially as the cells or organisms that lie on the line of the incision are killed.

For these reasons electrosection is of special value in removing malignant growths and performing cutting operations on infected tissue. The difficulty in stopping the escape of blood from the minute vessels during scalpel surgery of very vascular growths or growths in vascular organs, *e.g.*, the liver, can be surmounted by using the arc in place of the knife.

# CHAPTER XXXVI

# HISTOLOGICAL APPEARANCE

## 1. Of Tissue Subjected to Electrodesiccation

According to W. L. Clark, the tissue desiccated by his method shows the following changes under the microscope. The cells are shrunken, their nuclei condensed and elongated, and there is just a suggestion of cell outline. He likened their appearance to that of mummified tissue. The late Dr. Canti examined a portion of renal tissue which the writer had subjected to the English method. He made the following report: "The changes are very slight. The surface cells are not destroyed. The fulgurated area is best appreciated by a slight depression seen on examining with a hand lens." It is possible that if the action of the sparks had been continued the tissue would have exhibited changes like those described by Clark.

## 2. Of Tissue Subjected to Electrocoagulation

In order to ascertain the appearance of tissue after it had been coagulated by the diathermic current a portion of an undiseased kidney, which had been excised during post-mortem examination, was subjected to the action of the current. The coagulated portion and the adjacent uncoagulated parts were fixed and sections were cut. The following report was made by Dr. Canti: "The area treated is depressed. The cells on the immediate surface are devoid of nuclei and flattened out, giving the appearance somewhat of the horny layer of the skin. The cells below this area show good nuclear staining, but they are shrunken and separated by empty spaces. It is suggested that these spaces were filled with steam which tore the tissue apart. The area below this appears normal, but it must be remembered that heat is a histological fixing agent, and that while excessive heat would destroy the tissues, moderate heat would produce fixation similar to that produced by formalin. It would not, therefore, be possible to discern the line where heat fixation ended, seeing that the whole tissue was subsequently fixed by formalin."

From this report it may be concluded that the heat generated in tissue by the diathermic current does not completely destroy the structure of the cells, even in the parts where the heat is most intense. In most of the other parts the structure of the cells is preserved. For this reason it would be more accurate to speak of the *killing*, rather than the *destruction*, of tissue by the diathermic current.

### 3. Of Tissue Cauterised by the Arc

The arc produces much less destructive change than the heat which causes diathermic coagulation. It was mentioned above that the cells on the immediate surface of *coagulated* tissue are flattened out, devoid of nuclei, and giving the appearance somewhat of the horny layer of the skin. Tissue cauterised by an arc shows a very thin layer of flattened cells. This layer is discontinuous so that cells showing good nuclear staining are in many places to be seen on the surface. The spaces that are seen separating the cells of coagulated tissue are much less evident in tissue cauterised by the arc. As is the case with coagulated tissue it is not possible to discern the line where fixation ended, seeing that the whole mass was fixed in formalin after the electrosection. This report also was furnished by Dr. Canti.

# CHAPTER XXXVII

## TREATMENT BY ELECTRODESICCATION

### Comparison of the English and American Methods

When the English and American methods are compared, it must be admitted that the latter possesses one advantage : a condenser couch is not required. In the English method the patient has to be placed, as already stated, on a couch, and he is in a " live " circuit during the treatment. When the machine is in operation nobody can touch him without the passage of sparks. The operator must bring the point of the needle close to the part requiring treatment without making contact with the body. Although this can be accomplished without difficulty, special precautions must be taken when general anæsthesia is necessary. The anæsthetic must be administered *before* the machine is set in action. When the patient is unconscious everybody must stand clear, not only before the current is started, but while it is passing. But when the part to be treated is less accessible, *e.g.*, the base of the tongue or the vocal cords, and has to be brought into view by means of a metal speculum, the operator cannot conduct the electrodesiccation if the patient is on a condenser couch. The American method must then be employed. A greater range of adjustment is possible when the American method is used. Much good work, however, can be done by the English method and certain additional refinements of technique are possible by its means.

### Performance of the Operation

A general anæsthetic is necessary for infants and young children. It is necessary also when the part to be treated lies in sensitive and less accessible regions such as the neighbourhood of the base of the tongue. A local anæsthetic may be given when older children or nervous adults are to be treated. Local anæsthesia is necessary for many patients when the part to be treated has the sensitivity of the skin. In all cases it is helpful because it enables the operator to work with the deliberation that is not easy to practise when the patient flinches and starts every time he feels the pricking heat of the sparks. When the tissue to be treated is insensitive, as is the case, for example, in senile warts and some fleshy papillomas, it is seldom necessary to use a local anæsthetic.

Novocaine and adrenalin may be injected. If the tissue to be treated is quite small in amount the anæsthesia need not last for more than a few seconds and it may be procured by means of an ethyl chloride spray. When general anæsthesia is necessary it is essential to employ a non-inflammable anæsthetic in order to avert the risk of explosion. Desiccating sparks can easily set fire to an inflammable anæsthetic. When its vapour is mixed with air in the right proportion the sparks would explode the mixture.

Most of the writer's experience has been obtained with the English method of obtaining the sparks, the electrodesiccation being conducted in the following way. The machine is adjusted so as to yield very short sparks, say, 1 mm. long. Assume that a fleshy mole is to be treated. The sparks are directed over the entire surface. The surface instantly whitens in consequence of vaso-constriction. As the sparks continue to pass, the whitened surface gradually becomes pale brown. A thin crust forms in consequence of the drying of the superficial layers. The dried tissue presents an additional resistance to the current and before long the sparks cease to pass. If the mole were one which did not project more than about 1 mm. above the surface of the skin, no further treatment would be required. Suppose, however, that it projected from 5 to 10 mm. If longer sparks were passed, so as to continue the desiccation, they would dry the tissue to a slightly deeper level. But at the same time they would begin to carbonise the layers that have already been dried. In addition, it would be difficult to restrict long sparks precisely to the spots desired. They might avoid the dried parts and fall on to the normal tissue around. To overcome the difficulty the point of the needle may be placed in contact with the dried tissue or inserted into it. The sparks then will desiccate a layer of moist tissue immediately under the dried part. By proceeding in this way the tissue can be desiccated, layer by layer, to a gradually increasing depth until the entire mass is dried. The tissue shrinks progressively while it is being deprived of moisture. Eventually it is converted into a hard, dry, bloodless mass, which is much smaller than the original tissue.

Provided it can be done without loss of blood, it is a good plan to remove the desiccated tissue from the underlying parts. This saves the time that would be occupied by its separation by natural methods. It is advantageous also in another way. Fluid commences to accumulate under the desiccated tissue and if it cannot escape it may cause pain from pressure. In the writer's experience this is particularly liable to occur after the electrodesiccation of tissue on the sole of the foot.

If the part to be treated and the tissues adjoining it are not very vascular there will be no escape of blood after removing the desiccated part. If there should be a slow oozing from the capillaries it can quickly be stopped by directing sparks on the surface. If the bleeding is more rapid it is better to stop it by pressure with cotton wool. Sparks would be more likely to increase it. Their repeated application would convert the escaping blood into a black tar-like fluid which would " dirt " the operation and deprive it of its elegance.

After the treatment of very vascular growths, such as venous angiomata, it would be unwise to remove the dried residue because there may be some deep underlying vessels containing uncoagulated blood and these would bleed rather profusely. Separation by natural methods should be awaited. By that time a firm adherent thrombus will have formed.

The writer is sometimes asked for precise details as to the strength of the current to be employed, the time for which the sparks should be directed, etc. No exact information can be given. If an amperemeter is introduced into the circuit the needle does not move. Almost all the electrical energy is utilised in heating tracks of air to incandescence in the space between the point of the needle and the tissue—in other words, in forming sparks. Electrodesiccation is an art rather than a science and it can be learnt only by experience.

When the sparks are obtained by the American method the operation can be conducted on lines similar to those laid down. The following account is quoted from an article by W. L. Clark in "Principles and Practice of Physical Therapy."[1]

"The electrodesiccation effect may be produced in the tissue either by delivering the current through a short air-space to the tissue to be treated, by touching the surface with the electrode without an air-space intervening, or by inserting a needle electrode more or less deeply, the method of application depending upon the type of case under treatment, whether the affection is deep or superficial, and also on the degrees of tissue destruction desired."

From this description it is evident that the electrode may be *inserted* into the tissue, and it would seem from the passage quoted that the insertion may be made *before* the current is started. If this is actually the case the tissue immediately around the electrode will be *coagulated* before it is desiccated. In other words, electrodesiccation will be preceded by electrocoagulation.

### Electrodesiccation Preceded by Electrocoagulation

Electrocoagulation is sometimes practised intentionally (and sometimes it is performed unintentionally) before electrodesiccation. When the point of the needle electrode is close to the tissue, without making contact with it, the current passes in the form of sparks and the sparks desiccate the tissue. If the point of the needle makes contact with the desiccated tissue, a current again passes in the form of sparks because the desiccated tissue is a non-conductor. Suppose, however, that the needle had actually been inserted into the tissue before any current had been passed.

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[1] "Principles and Practice of Physical Therapy." Edited by Mock, Pemberton and Coulter. Maryland, Vol. II, 1933, p. 2.

There would have been no air space or dried tissue. No sparks, therefore, would have formed. But a change in the appearance of the tissue would have been noted a few seconds after the current had been started. The tissue immediately around the needle would have become pale and bloodless ; that is, it would have undergone coagulation. In other words, diathermic coagulation (electrocoagulation) would have taken place. When coagulation is brought about in this way the current generates heat by overcoming the resistance of the *tissues*. In the vicinity of the needle the density of the current is high enough to heat the tissue to the temperature at which it coagulates. If the current is not stopped, after coagulation has occurred, it will raise the temperature of the coagulation tissue to a degree high enough to boil away its fluid and render it thereby a non-conductor. The current then will pass in the form of sparks, which will perforate the dried coagulated tissue and desiccate a layer of moist tissue immediately around it. In other words, desiccation will follow coagulation.

It is evident, then, that in electrocoagulation the heat is generated by the current in overcoming the resistance of an *air space*, or that of *dried tissue*, and passing in the form of sparks. On the other hand, in electrocoagulation, the heat is generated by the current in overcoming the resistance of the *tissue* in its normal moist condition. Although it is possible to boil away the fluid from coagulated tissue, thereby rendering it literally *dry*, the expression *electro-desiccation* should be reserved for the procedure conducted by sparks. Tissue from which the fluid has been boiled away, after it has been coagulated, does not show the same appearance under the microscope as tissue that has been desiccated by sparks. In desiccated tissue the structure shows a further departure from normal.

From the quotation given on p. 417 (*q.v.*) it will be deduced that in Clark's method the tissue in contact with the needle is sometimes intentionally coagulated before it is desiccated. It is possible also, in the English method, to procure electro-coagulation of the tissue in the vicinity of the needle prior to desiccating it. All that is needed is to insert the needle *before* setting the machine in operation. The tissue in contact with the needle will coagulate almost at once, and soon afterwards there will be a passage of sparks between the embedded portion of the needle and the tissue in close vicinity to it. It is advisable, however, not to insert the needle more than a slight depth at a time. Otherwise there will be a likelihood of obtaining coagulation without a subsequent complete desiccation of the coagulated tissue. *The object of electrodesiccation is to procure a complete drying of the entire mass of the tissue under treatment.*

In the writer's experience it is advantageous, when treating certain abnormalities, to introduce the needle into the tissue *before* starting the current. Suppose, for example, it is desired to obliterate newly-grown blood vessels, like those that are sometimes seen on the nose and elsewhere, or teliangectases. They are very close to the surface, and if sparks are directed on the overlying epidermis they instantaneously whiten the surface and the underlying vessels disappear from view. This may be due, however, to *vasoconstriction* and the vessel may have escaped destruction. If, however, a fine needle is passed just below the surface of the skin, so that its point lies *in* the vessel, the current will coagulate it and almost immediately afterwards it will desiccate the minute amount of tissue that has been coagulated around the point of the needle.[1]

### Local Changes after Electrodesiccation

Fluid begins to exude in the tissue under the part that has been desiccated. After a few hours it forms a slight swelling. Gradually it begins to ooze out and form a scab. The scab slowly thickens and hardens, and after a few days it separates and leaves a smooth scar. It is rare for the patient to feel any pain after the anæsthesia has disappeared or during the process of healing. But if pain should be felt it can be relieved by bathing or soaking the part in a hot solution of boracic acid. The fluid that accumulates under the desiccated tissue is distinctly yellow in colour. Some patients say that pus has formed.

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[1] The coagulation of abnormal tissue by the diathermic current in the manner just described—the patient being on a condenser couch and the operator holding an earthed electrode—was originally described by Turrell, who termed it the "indirect" method of procuring diathermic coagulation in order to contrast it with the "direct" method in which the patient and the electrode are included in the same circuit. Some French workers practise this indirect method and call it "wireless diathermy" (*diathermie sans fils*).

If a growth or other abnormality of a mucous membrane is treated the desiccated part quickly absorbs moisture and acquires a white appearance.

There is no evident œdema in the tissues in the neighbourhood of the part that has been desiccated, nor does it develop afterwards, even when the operation has been performed on the eyelids. This, at any rate, is the writer's experience. It will be learnt later that œdema always develops in the mucous membranes in the vicinity of parts that have been treated by *electrocoagulation.*

### Complications

Complications after electrodesiccation are rare. Keloid is said to develop in some cases. But in only one of the writer's cases, one of nævus of the "port wine" type, did it appear. On the other hand, the writer has actually treated keloid by electrodesiccation and obtained soft scars. There is a remote possibility of the development of pigment in the scars left after the treatment of non-pigmented tissue. The writer, however, has seen this complication only in two cases. The possibility of the occurrence of malignant changes after the treatment of pigmented papillomata must be kept in mind. But of the many patients treated during the past fifteen years a few reported after the expiration of months, or even years, and no signs of malignant change were seen.

### Therapeutic Field

Various kinds of benign growth and other abnormalities of the skin and accessible mucous membranes, such as papillomas (pigmented and non-pigmented), warts of different kinds, certain types of nævus (angioma), pigmented areas of skin, keloid, clavus, leucoplakia, tuberculous nodules, have been successfully treated by electrodesiccation. American workers employ the method in the treatment of hæmorrhoids and malignant growths of the skin.

Particulars of the treatment of maladies of the kinds above mentioned and the results will be given in later Chapters.

## CHAPTER XXXVIII

# ELECTROCOAGULATION, ITS USES AND PRACTICE

### Comparison of Electrocoagulation with Electrodesiccation

In the preceding chapter it has been learnt that abnormal tissues can be killed by *desiccating* it. Electrocoagulation is practised for the purpose of killing the abnormal tissue by *coagulating* it. By the former method the tissue is deprived of its moisture. On the other hand, coagulated tissue remains moist. The reaction of the healthy tissues around a coagulated part is nearly as slight and painless as it is after electrodesiccation. On the other hand, the surrounding tissues become œdematous during electrocoagulation and exude lymph for many hours. Changes of this kind do not occur during or after electrodesiccation. Coagulated tissue sloughs away and an open ulcer is left during the process of healing. On the contrary, while desiccated tissue is separating, an adherent scab forms and covers the underlying healing tissue.

Tissue can be coagulated to a greater depth below the surface than it can be desiccated. It has already been mentioned that about 1 cm. represents the maximum depth to which desiccation can satisfactorily be conducted. As the active electrode has to be in actual contact with the tissue to be coagulated, it is possible to practise electrocoagulation in small spaces and narrow channels which cannot be kept in view while the current is passing. For these reasons the therapeutic field of electrocoagulation is wider than that of electrodesiccation. The former would appear to be a more thorough method than the latter in the treatment of malignant disease, more especially in ulcerating than in fungating growths.

## Factors Determining Suitability for Treatment by Electrocoagulation

### (1) *Situation of the Pathological Tissue*

If abnormal tissue is to be treated by diathermic coagulation it must be *accessible*—that is to say, within reach of the active electrode, because this electrode must be placed in contact with it. Growths and infective granulomata of the skin, and of the mucous membrane of the mouth, nose, tongue, pharynx, larynx, œsophagus, rectum, bladder and cervix uteri can be treated. Growths which arise from the wall of the stomach and intestine and project into the lumen might be treated—after exposure by surgery—if the destroyed tissue could slough into the lumen and so make its way to the exterior, measures being taken to render its escape elsewhere anatomically impossible. Growths of the upper jaw have been treated by electrocoagulation after rendering them accessible by scalpel surgery.

### (2) *Extent of the Pathological Tissue*

If growth has infiltrated into parts which cannot be destroyed without risk, no hope can be entertained of complete removal. Diathermy is no respecter of tissues.[1] Normal tissue and new growths are killed alike if they lie on the path of a current of sufficient intensity to coagulate the growths. Widespread neoplasms are, however, in many cases, suitable for *palliative* treatment by diathermy, and the benefit, though temporary, may be considerable.

Growths which are less widespread but too extensive for the scalpel are, in many cases, suitable for diathermy. Cases of this kind formed the bulk of those which were treated during the first decade of the use of surgical diathermy at St. Bartholomew's Hospital. The results were so encouraging that the treatment was tried for earlier cases. At the present day some surgeons employ diathermy for the treatment of malignant disease of the mouth and throat, and some prefer it to the knife even in cases which, hitherto, they would have treated by excision.

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[1] Although the lethal temperature for malignant tissue is slightly lower than that for normal tissue, no method has yet been devised whereby diathermy might be applied so as to heat infiltrated tissue throughout to the lower temperature. The task would be one of great difficulty.

### (3) *Condition of the Patient*

If the general condition of the patient is bad, and cachexia is present, treatment by diathermy is inadvisable. If performed on such cases, pain will probably follow, and, if present, it may be aggravated. There is also a risk of hæmorrhage after the operation. The presence of glands enlarged by the growth is not a contra-indication against diathermy if cachexia is absent. They may be excised before or after the diathermy, at a separate operation.

## Methods

On pages 389–398 a number of experiments were described in order to explain the various ways of utilising the tissue-coagulating power of the diathermic current for surgical purposes. These methods, and the purposes which they serve, can briefly be summarised as follows.

In the *first*, the current is passed through the pathological tissue itself, the object being to coagulate it *en masse*. The active electrode is a disc or ball, which is placed *on* the tissue, or a needle, which is inserted *within* it. After it is coagulated it is left to separate spontaneously by the process of sloughing.

In the *second* method, the current is utilised for the purpose of coagulating a layer of healthy tissue around and below the pathological portion ; in other words, to procure *circumvallation*. The active electrode is a needle. The object of this method is to isolate the pathological tissue from its healthy surroundings and leave it for removal by another method—usually *electrosection*.

In the *third* method, circumvallation is combined with excision. As fast as the isolating barrier of coagulated tissue is formed it is cut into two layers so that the pathological tissue can be removed. The active electrode is a short narrow blade.

In the *fourth* method, a snare is used as the active electrode, and the object is to remove a projecting mass of tissue, leaving the divided surfaces coagulated.

### Choice of Method

The choice of method is influenced by the degree of accessibility of the pathological tissue. If the tissue is malignant, the selection of the method will also be influenced by the extent to which it is spread ; in other words, whether it is *eradicable* or *ineradicable.*

If the pathological tissue is situated on the exterior of the body, or in the mouth, or in certain parts of the oro-pharynx, it can be seen without the assistance of special viewing instruments while the coagulation is going on ; it can then be described as " easily accessible." If, at the same time, it is *non-malignant,* the method to be employed is the one first described, viz., that in which the tissue itself is coagulated.

If, however, it is *malignant,* but *eradicable,* the second or third method may be employed. The synchronous circumvallation and excision with a blade electrode is difficult to perform without loss of blood. On the other hand, if a preliminary circumvallation is performed the growth can be excised with greater dexterity, neatness and safety by means of the cutting-arc (electrosection).

If the pathological tissue is malignant and also *ineradicable,* the only method that can be practised is the electrocoagulation of as much of the malignant tissue as is possible.

If the tissue to be treated is a non-malignant *polypus,* the fourth method—that in which a snare is used as an active electrode—should be employed.

If the growth is situated behind the cricoid cartilage, within the œsophagus, bladder or rectum, the active electrode can be brought into contact with it but it cannot be freely manipulated. The growth will then be described as " less accessible." The only method that can be practised is that in which the pathological tissue itself is coagulated —circumvallation and excision being impossible.

Growths within the bladder or rectum can, however, be rendered easily accessible by exposing them by means of the scalpel. In the same way growths within the antrum and other sinuses of the nose and the nasopharynx can be exposed and coagulated by the current.

### Anæsthetic

If diathermy is to be applied to small portions of tissue, in less sensitive regions, that can be destroyed in a few seconds, and with weak currents, no anæsthetic is required. If a large mass is to be destroyed the heat will accumulate, especially if stronger currents are used and for longer periods, and the tissues will become unbearably hot, so that an anæsthetic is necessary. A general anæsthetic is necessary if the patient cannot be trusted to remain still, especially if the treatment is to be applied to less accessible parts, such as the larynx and nasopharynx.

Ether should never be used when surgical diathermy is performed in the mouth, throat or air passages. Sparks would certainly explode ether vapour and air when mixed in the right proportions. It is not safe to use ether even if the site of the operation is the other end of the body. If ether vapour is in the atmosphere the theatre might be wrecked by explosion. At least one accident of this kind has occurred.

### The Indifferent Electrode and its Position

The indifferent electrode should be placed on the trunk, either chest or abdomen, when the patient is lying on his back. To ensure even contact with the skin a folded towel, measuring, when folded, say, 8 in. by 10 in., well soaked in hot salt solution, is interposed between the metal and the skin. The metal plate may measure about 6 in. by 8 in. It should be bandaged in position. It is a matter of great importance that the moistened towel should make contact at all points with the body, and that it should not get dry, otherwise the skin will be burnt, particularly if long applications are made. It is very necessary that strong salt solution, not less than 10 per cent., should be used for saturating the towel. If weak solution or tap water are used they will present a high resistance to the current, their temperature will rise, and the skin may be scalded.

## Active Electrodes

When the tissue to be coagulated is on the exterior of the body or in easily accessible regions, the active electrode may be a disc or ball. A ball electrode is useful when an ulcer is to be treated and its edge is irregular and its base uneven. If a disc electrode is used the size selected will depend on the surface area and depth of the part to be coagulated. If its depth is greater than about 1 cm. it is better to use a single needle electrode rather than a disc more than 1 cm. in diameter. The coagulation may be commenced, however, by means of a disc of the diameter mentioned. The deeper parts may then be coagulated by means of a needle electrode.

Special electrodes are used for the coagulation of growths in the bladder or œsophagus or behind the cricoid cartilage. These will be described later.

In certain circumstances the indifferent electrode may be replaced by a second *active* electrode, both being placed in contact with the tissue to be destroyed. The current will then be confined to the tissue and its density will be high throughout its path. Two active electrodes may be used when the tissue to be coagulated projects well above the surface, as in the case of a fungating growth.

## Regulation of the Diathermic Current

Before the diathermic current is switched on, the electrodes must always be in position. The disc is placed in the desired position, and it must not be moved from the body until the current is switched off; otherwise torrents of sparks will dart between the electrode and the body and perhaps burn neighbouring parts; while anyone who touches the indifferent electrode, or the uncovered skin of the patient, or the uncovered end of the active electrode, may receive sparks.

The current should be started from zero, and its strength gradually increased. The regulating handle which controls the strength of the current should be moved from zero towards maximum, and about ten seconds should be occupied in the movement. Just before sparks appear, or at the moment when they first appear, the current should be stopped, and the regulating handle moved to zero. The disc is then placed on an adjoining region, and the current again started and increased as before. The process is repeated until all the tissue to be killed has been coagulated.

The changes which take place around and under the disc, and the sounds due to the escape of steam and passage of sparks, have already been described. The operator can soon learn, after a little practice on excised tissue, the correct time for stopping the current. The passage of sparks between the edges of the disc and the uncoagulated tissue is not harmful, although muscles in the vicinity may contract. The passage of sparks is an indication that the tissue immediately under the disc has dried. Dried tissue may adhere to the electrode.

When the single needle electrode is used and inserted in position the current should be increased gradually, as before. It should be stopped at the moment when coagulation is visible on the surface around the shaft of the needle. As mentioned before, the coagulation begins at *the point* of the needle and spreads up and around the shaft.

If the tissue in contact with the electrode becomes quite dry it will adhere to it. Sometimes it adheres so tenaciously that a portion of the coagulated tissue comes away with the metal when the electrode is removed. A sharp instrument may then be necessary to remove the adherent tissue. If even a thin layer of dried tissue remains on the metal when the electrode is re-applied, sparks will quickly appear when the current is started and the tissue will not coagulate to the proper depth.

It is tempting, after coagulating the malignant tissue, to scrape it away with a Volkman's spoon or blunt instrument. This is not to be recommended, because bleeding is almost certain to occur. In the lowermost region to which the coagulation has extended, only the fixed tissues will be coagulated, not the circulating blood, and the latter will escape if the coagulated tissue is scraped away.

### Results of Diathermic Coagulation of Tissue

#### (1) *Local*

The tissue in the region of the coagulation quickly becomes œdematous. The œdema begins during the operation. It is most apparent when diathermy is applied to growths of mucous membranes. It persists after the heated tissue has regained its normal temperature, and may not subside until one or two days have passed. Exudation of lymph begins soon after the appearance of the œdema. It persists while the œdema lasts and may be profuse for twenty-four hours and cause thirst.

Œdema may appear in the eyelids after coagulation of growths or ulcers of the face near the eyes. Swelling of the lids is apparent a few hours after the operation and may attain a degree sufficient to prevent the patient from opening his eye. The œdema subsides gradually and the lids regain their normal condition in a day or two. Œdema of the eyelids may occur after diathermic coagulation of growths or ulcers of the face at some distance from the eye, *e.g.*, on the lower part of the cheek.

Considerable swelling of the neck occurred in a case in which the author coagulated enlarged tonsils, using a disc electrode.

The coagulated tissue begins to separate after two or three days. The separation of the slough is complete in two to three weeks.

Granulation tissue quickly fills the cavity left by the slough, and new epithelium covers it. The new tissue does not shrink or form adhesions with parts which may be in contact.

Keloid sometimes develops in the skin. This is more likely if the coagulation has been restricted to the skin. It has been seen in cases in which the skin was accidentally coagulated under the indifferent electrode ; also in some cases of lupus which were treated by diathermy.

### (2) *General*

Shock rarely occurs after coagulation of tissue by diathermy, even if a considerable mass has been destroyed. In all the cases in which the writer has made inquiry, signs of shock, such as fall of temperature, cold extremities, feeble pulse, etc., were not observed after the operation. The patients, after return from the operating theatre, are packed in blankets with hot-water bottles, and the signs mentioned do not occur. A rise of temperature is sometimes noted on the day after the operation, but, unless complications occur, it subsides on the third day. It usually reaches 99·4° or 100°, rarely a higher value.

Pain is slight or absent, and if present before the operation, is usually relieved. The degree of discomfort following the greater number of cases of operation by diathermy is surprisingly small, if the general condition of the patient is fairly good before the coagulation and cachexia is not present. The patient is able to sit up in bed on the day after the operation and get up on the third day. The separation of the slough is a source of discomfort more to the attendants of the case and the other inmates of the ward than to the patient himself, as the odour is disagreeable and penetrating. After the separation is complete the odour disappears.

If the general condition is bad before the operation and cachexia is present, the patient suffers much after the operation and pain is increased. As noted above, it is inadvisable to perform electrocoagulation on such cases.

## Complications

The complications which may arise after diathermic coagulation are few, and most of them can be prevented.

The œdema which develops during and after the coagulation may cause obstruction of the glottis when growths in the vicinity of the larynx are subjected to diathermy. The risk of asphyxia can be averted by tracheotomy. This operation should be performed before the application of diathermy, because the obstruction may occur later, when the surgeon is away.

Œdema is likely to obstruct the lumen of the pharynx or œsophagus when diathermy is applied to growths which are situated in these passages and narrow the channels. The electrode maintains their patency during the operation, but tubes should be passed and kept in position as soon as the diathermic coagulation is complete.

If an artery of appreciable size, *e.g.*, the lingual, lies in close vicinity to a growth which has been coagulated by diathermy there is always the likelihood of hæmorrhage if the vessel or its parent trunk has not been ligated previously. The hæmorrhage occurs when the separation of the slough is well advanced, that is, in about a week to ten days after the operation.[1]

The lingual artery was the commonest source of this so-called "secondary" hæmorrhage before the custom of ligating vessels, prior to diathermic coagulation, was adopted. Secondary hæmorrhage has also occurred from the temporal and ascending pharyngeal arteries as well as from smaller vessels.

If the general condition of the patient is bad and cachexia is present there is a likelihod of hæmorrhage at an earlier date.

Septic infection of the slough, or of the underlying tissue after the slough has separated, is a very rare occurrence. Suppuration in the glands receiving lymph from the coagulated region occurred in two of the cases treated at St. Bartholomew's Hospital. In one of these septic thrombosis occurred.

Septic broncho-pneumonia is an occasional complication after diathermic coagulation of growths of the mouth, pharynx and larynx, but it occurs less commonly than after cutting operations with the scalpel.

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[1] The reason for the hæmorrhage will be understood when it is remembered that at a short distance beneath the active electrode the temperature is not high enough to coagulate the blood within a vessel of appreciable size. It was explained on p. 402 that the blood passes along the vessel and through the heated region too quickly to be coagulated by heat, even though the heat may be intense enough to coagulate the vessel walls. Although a thrombus will form after the coagulation of the wall of the vessel, it will probably be dislodged when the slough is separating—especially if the separation is manually aided. In Fig. 119, p. 402, there is represented the stratum of tissue (3) in which the temperature is high enough to coagulate the non-moving tissues (including the vessel walls), but not high enough to coagulate the blood before it has moved out of the heated region.

Sudden death has never occurred, as far as the author is aware, *during* coagulation by diathermy. During convalescence it occurred in one case without apparent cause, and as autopsy was not allowed, the reason was not ascertained. This was a private case of carcinoma of the tongue. The anterior portion of the organ was excised by the blade electrode. The operation was lengthy and over an hour was occupied in its performance.

In another case death occurred about four hours after completion of the operation. The patient, a man aged sixty-six, had a carcinoma invading part of his tongue, faucial pillars, floor of mouth, and soft palate. No enlarged glands were felt; there were no signs of secondary growth, and the general condition of the patient was good. No shock followed the operation. The patient had not fully regained consciousness after the anæsthesia. No autopsy was allowed in this case.

## After-care

Until the slough has separated and healing is complete the wound requires simple surgical dressing if on the exterior of the body. If on the mucous membrane of the mouth or throat, frequent irrigation with antiseptic and deodorising solutions, such as hydrogen peroxide or listerine, is advisable.

It is of the utmost importance that the patient should report at regular intervals so that the site of the treatment can be examined. If recrudescence occurs diathermy should be repeated.

# CHAPTER XXXIX

## ELECTROSECTION

BY
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High-frequency electric currents have been used for many years for the destruction by coagulation of malignant and other neoplasms, but it is only recently, and especially since the introduction of the three-electrode thermionic valve into high-frequency apparatus, that the clean incision of tissues with the minimum of coagulation—" electrosection "—followed, as it can be, by perfect primary healing, has been practised to any appreciable extent.

For electrosection two electrodes are required. The " indifferent " electrode is a large plate of malleable metal or of metallic gauze, and is applied to the skin of a limb or some part of the trunk distant from the area of operation ; it is bandaged firmly either directly to the skin or with the intervention of several folds of lint soaked in strong saline solution. The other, the " active " electrode, is a small metal disc or knob where coagulation is the effect desired, or a fine-edged knife, needle, or piece of fine wire where cutting is intended. The actual cutting of the tissues is effected by a small electric arc which forms immediately in advance of the electrode, and which splits the tissues by molecular dissolution ; there is no need for actual contact between the electrode and the tissues, and still less for any pressure of the electrode upon them such as is required in scalpel surgery. No advantage accrues, therefore, in using a knife as the active electrode, be it never so finely edged, since the tissues are severed before it comes in actual contact with them. After experimenting with numerous kinds and shapes of active electrodes—knives, needles, wires—constructed of various metals, I now use fine tungsten wire only: 0·005 gauge for the skin and 0·008 for the deeper tissues. The finer the electrode and the more closely it approaches a theoretical point the more certain is a purely cutting effect, free from coagulation. A fine needle as the active electrode has the advantage over fine wire of stiffness, and therefore of better control, but since it must necessarily be of wider bore than the fine sizes of tungsten wire already referred to it produces corresponding coagulation. Further, to obtain the purest cutting effects the electrode must be drawn rapidly across the tissues, for if allowed to rest at any spot, coagulation will there occur. Obviously, then, the technique of electrosection is very different from that of scalpel surgery, and considerable practice and experience are required to avoid any pressure of the electrode upon the tissues, to acquire the correct speed of its passage across them, and to gauge the strength of current requisite for their clean division having regard to the very different resistances they offer to the high-frequency current. Not realising these points, some surgeons, after a trial much too short to enable them to form a correct idea of its possibilities, have abandoned electrosection in disgust.

### Action on the Tissues

Using the undamped high-frequency current from a triode valve machine and applying it with a light and rapid stroke of the 0·005 gauge tungsten wire electrode, the skin, held preferably slightly on the stretch, can be divided as cleanly as with the sharpest scalpel, with no charring or coagulation of the edges that is visible to the naked eye, and with only just sufficient microscopic coagulation to seal up the lymphatics and capillaries, and to "cap" and obtund the sensory nerves. Such an incision can heal by the most perfect primary union, leaving a scar indistinguishable from that after a scalpel incision, and with decidedly less pain during the healing process. For the deeper tissues the 0·008 wire gives a slightly greater degree of coagulation without, however, preventing primary union. These deeper tissues are divided more quickly or more slowly than the skin according to their comparative resistance, fatty tissue being the most resistant and the slowest therefore in division. Time is gained by increasing the strength of the current when dividing the resistant tissues, and this is especially noticeable in the "radical" breast operation, where the extensive undermining of the skin-flaps has to be carried out entirely in the plane of the resistant superficial fat. Muscle is definitely less resistant than the skin, and for its division the current should be diminished, as otherwise

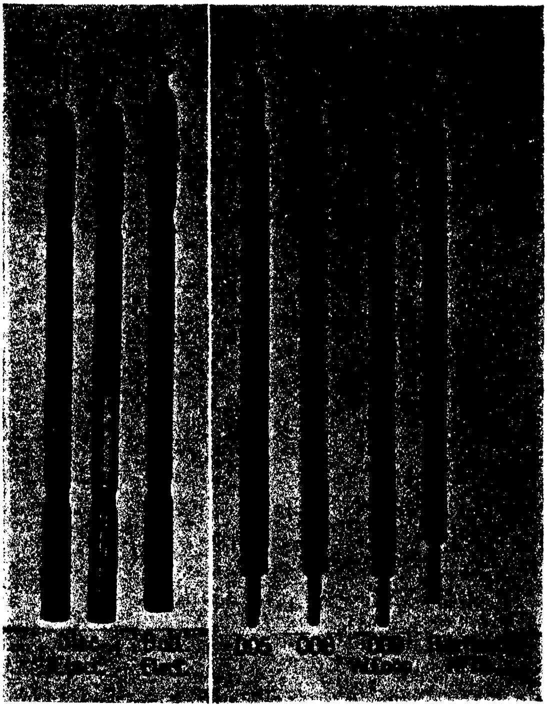

Fig. 121. Fig. 122.

In Fig. 121 are illustrated the "Active" Electrodes for Electrocoagulation, and in Fig. 122 those for Electrosection (Tungsten wire ·005 and ·008 in. in diameter).

(*Note.*—In Fig. 122, ·005 should be ·008, and *vice-versâ.*)

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muscular twitchings, from "undertones" of the oscillations, may hinder progress. In spite of the claims made by their manufacturers, of the many machines I have tested personally I have not yet found one giving a cutting current from which muscular contractions are entirely eliminated. With some machines this muscular twitching is so marked as to entail the risk of structures being forced against the electrode and divided unintentionally, as when in performing laparotomy twitching of the rectus abdominis may lead to premature incision of the peritoneum and even of an underlying viscus. Cartilage is little resistant and can be divided with the greatest ease, while bone is so highly resistant that, although it may be "cooked" and rendered friable, it cannot be cut. Liver and kidney offer but slightly greater resistance than the skin, and incisions made into them with the cutting current heal well; moreover, the tissues in the immediate vicinity of the incision seem to be rendered less friable than is normal, so that these incisions can be sutured more firmly and more accurately than those made with the scalpel, besides showing definitely less hæmorrhage.

For electrocoagulation, in contrast to electrosection, the requisite conditions are very different, and in obtaining the most perfect manifestation of each the essential differences may be tabulated thus :—

| *Electrosection requires—* | *Electrocoagulation requires—* |
|---|---|
| 1. Very high frequency, | 1. Lower frequency, |
| 2. Short wavelength, | 2. Longer wavelength. |
| 3. Lower voltage. | 3. Higher voltage, |
| 4. High amperage, | 4. Lower amperage. |
| 5. "Undamped" wave, | 5. "Damped" wave. |
| 6. Very fine electrode (fine wire) | 6. Larger electrode (needle, button, plate). |
| 7. Electrode moved quickly over tissues, | 7. Electrode moved slowly, or held in contact. |
| 8. Triode valve apparatus. | 8. Spark-gap apparatus. |

The greater the cutting power of any given current the less is its coagulating power, and *vice versâ*. It cannot, in fact, be too clearly recognised that cutting and coagulation are definitely antagonistic processes, and the type of current yielded by most of the commercial machines is a compromise between them. The purely undamped wave—the best for electrosection—cannot be produced by any spark-gap machine but requires a triode valve apparatus. Nevertheless, by superimposing the wave-trains from a spark-gap machine closely upon one another a type of wave can be obtained which approximates to, though it never quite reaches, the even character of the purely undamped wave. On the other hand, the strongly damped wave—the best for electrocoagulation—is most suitably obtained from a spark-gap machine, although by varying the voltage and amperage of a triode valve current the wave-train can be so modified as to yield a satisfactory coagulating current. The conclusion to be drawn from all this is that while fairly satisfactory electrosection and electrocoagulation can both be obtained from either type of machine, a triode valve is necessary for the most perfect exhibition of electrosection and a spark gap for that of electrocoagulation. Since, to my mind, it seems the more important for general surgical use to obtain good cutting and primary union of the wound, I believe that the future lies with the triode valve apparatus. It is comparatively recently that such machines have been produced in this country, though long in use in America and France. In the latter, Bordier has been especially prominent in developing the triode valve apparatus which, he states, has the advantages of lower consumption of current and greater output, yielding more than double the wattage of the best spark-gap machine for the same amperage and voltage fed into it ; moreover, it is quite silent, while a spark-gap is always more or less noisy, no odour of ozone or oxides of nitrogen is emitted, and no coal-gas or alcohol is needed such as some spark gaps require. Theoretically the ideal would be the use of both types, the surgeon performing the cutting portion of the operation with the triode valve apparatus, and his first assistant following with the coagulating current from a spark-gap machine and coagulating any bleeding points ; this is sometimes carried out. In most machines, however, the two types of current are produced separately, and either can be switched on at will to the same active electrode. In general surgery the coagulating current is used nowadays almost exclusively for the arrest of hæmorrhage. The coagulation of large masses of tissue, leaving the coagulated portion to separate naturally—a method much in vogue in the early days of surgical diathermy—is seldom now employed; owing to the varying resistances of the tissues it is impossible to predict the direction and extent of the resulting coagulation, so that on separation of the coagulated tissues it may be found that there has been unexpected necrosis of the wall of one of the larger blood vessels—with resultant secondary hæmorrhage. Where a large mass of tissue has to be removed it is better practice to excise it with the cutting current and employ the coagulating current to arrest hæmorrhage from the cut surface. With the cutting current there is rather less hæmorrhage from the capillaries than with the scalpel, and this soon ceases. Vessels of any size, however, require to be picked up with artery forceps and, at the conclusion of the operation, either ligatured in the ordinary way or "coagulated" by lifting the forceps

FIG. 123.—Coagulation of a blood vessel, temporarily occluded, with artery forceps, by touching the forceps with the active electrode charged with the "coagulating" current. (Reproduced by kind permission of *The Lancet*.)

away from contact with any other instrument or tissue and touching it for a few seconds with the electrode charged with the coagulating current (Fig. 123). On removing the forceps the coagulated vessel is gently wiped with a swab, when the bleeding will usually be found arrested; should it, however, restart, it is better to seize the bleeding point again with forceps and ligature it. Single small spouters in the course of dissection may be seized with the teeth of the dissecting forceps usually held in the left hand and coagulated by touching the forceps with the coagulating current (Fig. 124).

FIG. 124.—Coagulation of a bleeding point by picking up with the teeth of dissecting forceps, which is then touched with the active electrode charged with the "coagulating" current. (Reproduced by kind permission of *The Lancet*.)

This closure of vessels by coagulation can be effected very rapidly as compared with ligation, and in an extensive operation such as that for breast carcinoma considerable time can be saved. It is preferable, however, to ligate branches divided close to a large parent vessel, such as the axillary, since, although they can be securely closed by coagulation yet there is a risk that the process may occasionally extend to the junction with the parent trunk, and result either in its thrombosis, or in secondary hæmorrhage.

### Rate of Healing

Provided that an equally rigid aseptic technique be adopted as is employed in scalpel surgery, my experience is that operations performed by electrosurgical methods—the cutting current for the incisional work and the coagulating current for all but the largest vessels, and using fine tungsten wire as the electrode—are attended by primary healing with a frequency at least equal to that of scalpel surgery. On theoretical grounds one would expect healing to be rather slower since, with the cutting current, there must necessarily be some slight necrosis of the wound surface, however microscopic, which will require to be dealt with by the phagocytes as a preliminary step towards healing. I, therefore, usually retain the skin sutures two or three days longer than when scalpel surgery has been used, though I am not convinced that this is essential. The ultimate scar can be just as inconspicuous, as supple and as strong as after the scalpel, and some of the scars upon the face and neck of female patients, of the inconspicuousness of which I, and they too, are most proud, have resulted solely from electrosection.

Experimental investigations upon animals have yielded rather inconstant results. Ellis (1), operating with the cutting current upon 120 dogs, under ether anæsthesia, with aseptic technique, and with scalpel incisions as control, found that incisions in the muscles or in the muscular wall of the stomach healed just as readily and as strongly when made with the cutting current as with the scalpel. Of the skin incisions, however, only 60 per cent. of those electrically produced healed by primary union as against 97·5 per cent. in the control scalpel wounds, and even when primary union did occur the tensile strength of the former was rather less during the early period of healing and did not equal that of the latter until the twenty-fourth day. He attributes this difference in healing between muscle and skin to the relatively high electrical resistance of the stratum corneum, to penetrate which needs such a density of current as necessarily to produce some coagulation of the lesser resistant layers of the skin, thus delaying the healing process. Pearse and Ward (2), also experimenting with dogs under ether anæsthesia, and with strict surgical asepsis, found that electrosurgical incisions and partial excisions can be executed upon the liver and kidney with only slight primary hæmorrhage, without any secondary hæmorrhage in the absence of infection, and with uneventful healing, although the scarring was usually more extensive than after the scalpel. Beverley Chew Smith (3) in a series of animal experiments and clinical observations found that union in electrically made wounds is no less firm than in scalpel incisions, and Lilienthal (4) comes to a similar conclusion and considers that an electrically made wound is more likely to be aseptic than one made with a knife.

The mechanism of the cutting effect of the high-frequency current is not precisely known. Jellinek (5) considers that it is merely a thermal effect, the rapid conversion of the liquid contents of the cell into steam, with its consequent sudden expansion, actually bursting the cell, while Oudin (6) ascribes it to the assumption by the atoms of the tissues of a new rate of vibration, thus leading to their molecular destruction. When the active electrode approaches the skin very closely a minute spark, readily visible in the dark, passes between the point of the electrode and the skin ; the electrode and the tissues act, in fact, as plates of a condenser and the intervening short air-space as the spark gap. This sparking occurs whether the electrode is fed with the cutting (undamped) or the coagulating (damped) current. In the former event, however, the spark, as seen in an instantaneous photograph, is a compact narrow pencil of flame whose action is strictly localised, whereas in the latter it is a broad spray irregularly distributed over a wide area of the tissues. This difference in the character of the spark is to be correlated with that between the uniformly sustained oscillatory potential of the undamped wave-train and the constantly varying potential of the damped variety, the current density of the former being considerably the greater and producing a persistent

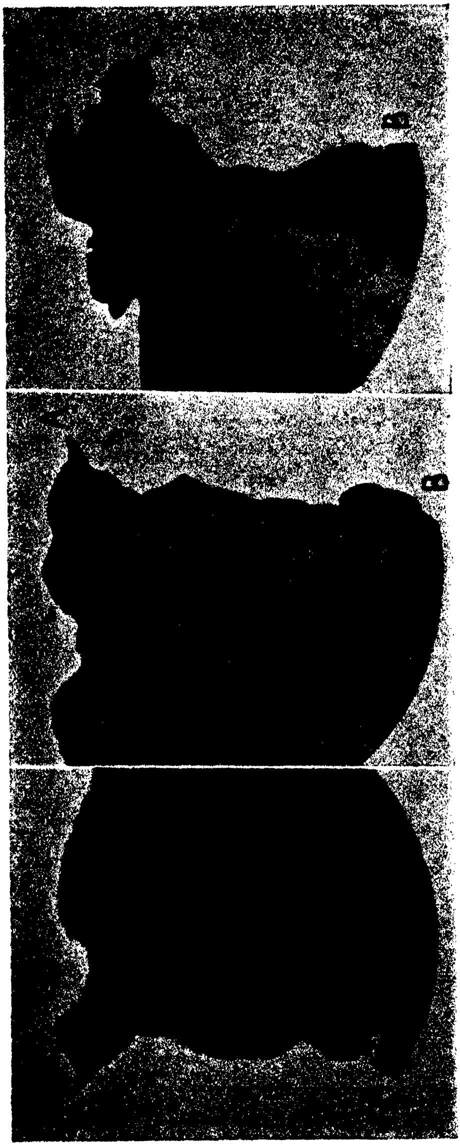

Fig. 125. Fig. 126. Fig. 127.

Figs. 125-127.—Sections (× 35) showing effect of various incisions on skin and subcutaneous fat. The incised edge runs from A to B. Fig. 125, "cutting" current and 0·005 tungsten wire electrode. Fig. 126, "cutting" current and 0·008 tungsten wire electrode. Fig. 127, "coagulating" current and 0·005 tungsten wire electrode. (Reproduced by kind permission of *The Lancet*.)

ionisation of the air-gap. McLean (7) insists strongly that "adequate current density is the sole general requirement for cutting by electricity"; it is easier technically to maintain this density with undamped than with damped wave-trains but "mysterious effects are resident in neither."

In spite of certain opinions to the contrary, no conclusive evidence has yet been adduced that the high-frequency current exerts any bactericidal action on the tissues other than that of the heat incited by their resistance to its passage, or that it possesses any selective destructive action upon malignant cells; doubtless these are destructible at a temperature rather lower than that at which the cells of normal tissues are destroyed, but the difference is insufficient to be of any practical value.

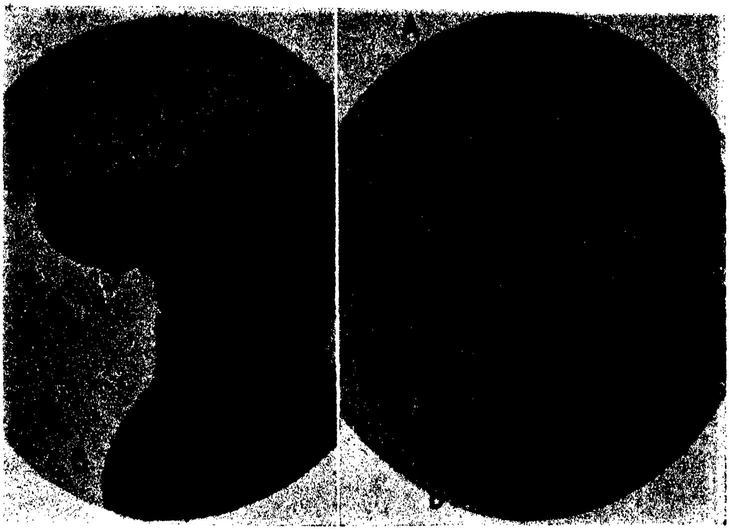

FIG. 128. FIG. 129.

Liver incised with "cutting" current and 0·005 tungsten wire electrode. Fig. 128 (× 50). Fig. 129 (× 250). (Reproduced by kind permission of *The Lancet*.)

My colleague, Dr. G. L. Loveday, the director of the clinical laboratory at the Manchester Royal Infirmary, has prepared for me many slides illustrating the microscopical appearances of most of the tissues of the body after section with the "cutting" current from a triode valve machine applied with the tungsten wire electrode (Figs. 125 to 132).

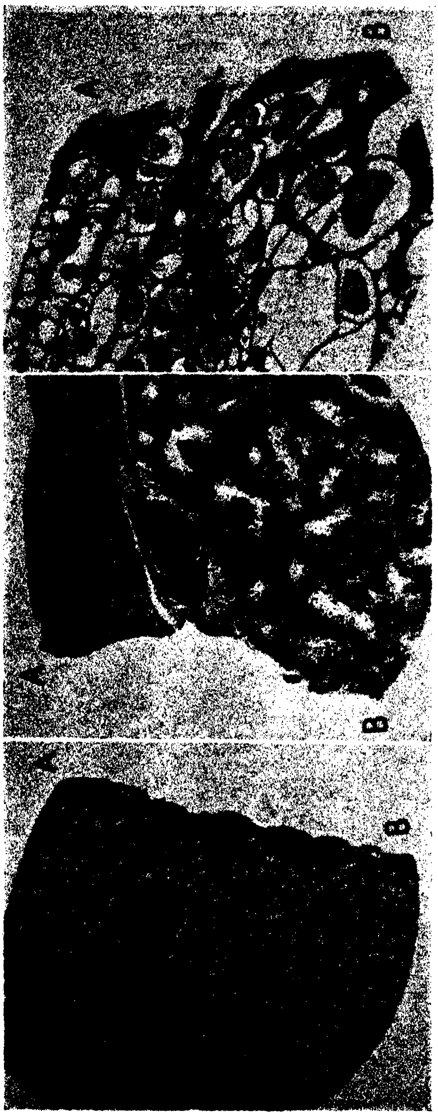

FIG. 130. FIG. 131. FIG. 132.

Sections (× 35) showing effect of incision with "cutting" current and 0·005 tungsten wire electrode. Fig. 130, kidney. Fig. 131, testis. Fig. 132, thyroid. (Reproduced by kind permission of *The Lancet*.)

The extent of coagulation necrosis is astonishingly small, and in many sections Dr. Loveday reports " practically no necrosis." It requires the section to be cut fairly thick and to be stained deeply before necrosis can be demonstrated to an extent sufficient to show upon a lantern slide.

### Advantages and Disadvantages of Electrosurgery

In the surgery of malignant disease it is generally accepted that malignant cells can be transplanted during the course of a surgical operation if cancerous tissue—either the primary growth, the secondary glands, or the numerous "permeated" lymphatic channels between these—be traversed by a scalpel which passes thence into healthy tissues; many local recurrences are thus explicable. If, however, the scalpel be replaced by the fine high-frequency electrode the intense heat generated at its point of contact with the tissues will suffice to destroy instantaneously any such liberated cells and so prevent their local transplantation, while the divided lymph and blood capillaries are immediately sealed and these further avenues of dissemination effectively closed. So obvious is the superiority of the high-frequency electrode over the scalpel in this respect that it is now generally recognised as the safer instrument in the surgery of all malignant disease. The same may be said of its employment during "biopsy" upon any tumour suspected of malignancy, or where incisions have to be made into, or in the close proximity of tissues already the seat of bacterial infection—such as carbuncle, cellulitis, etc.

In the surgery of non-malignant and non-infected conditions, however, we are upon more debatable ground, and it has been in an attempt to ascertain for myself the possibilities of electrosection in general surgery that I have used it so largely and in such a variety of operations during the past six years. In comparison with scalpel surgery electrosection has, I am convinced, certain definite advantages, and foremost amongst these I would place the *lesser amount of after-pain*, not only in the immediate post-operative period, but throughout the whole course of wound healing. In dividing nerve-fibres the high-frequency current seals over their ends in such a way as to render them much less sensitive than after division with the knife, and in extensive operation wounds, such as those of large amputations of limbs or of "radical breast" operations, this difference is strikingly manifest. On three occasions I have performed, with electrosection, the radical breast operation where I had previously removed the other breast with the scalpel, and in each instance the unsolicited testimony of the patient was overwhelmingly in favour of electrosection. The same contrast is well shown in operations upon specially sensitive regions such as the anal canal, and the pain following operations for hæmorrhoids, particularly that associated with the first action of the bowels, is markedly alleviated.

It is usually stated that *hœmorrhage* is lessened, but I am not convinced that this is so to any great extent if the purely cutting current only is used. With this, oozing from capillaries is slightly less and is earlier spontaneously arrested, but vessels of any size require to be picked up with forceps much as in scalpel surgery, and either ligatured in the usual way or sealed with the coagulating current. Some high-frequency machines deliver a current which is a compromise between the purely cutting and coagulating currents, and with these hæmorrhage is undoubtedly less but only because of the greater degree of coagulation produced over the entire wound surface, with its consequent lesser probability of perfect primary union.

There is no doubt that *shock* is definitely less with electrosection, partly from the diminished afferent impulses due to the sealing up of divided nerve-fibres, partly from the slight diminution in hæmorrhage, and partly from the increased temperature of the severed tissues—an effect readily appreciated in the radical breast operation, where the pectoral muscles feel quite hot even to the rubber-gloved hand. The sealing of blood vessels by running the current along an artery forceps temporarily applied thereto, in place of using ligatures, may lead in a large wound to a considerable saving, not only in time but also in expense, particularly if the surgeon be one who uses catgut alone for ligature material; moreover, the lesser amount of foreign body thus left behind is conducive to better wound healing. Owing to the intense heat developed at the point of the electrode a wound made by electrosection is more likely to be aseptic than if made with a scalpel, and Howard Kelly (8) considers that in a wound left unsutured healing is more rapid that in the average surgical case ; less scar tissue is formed and the resultant scar is softer and more pliable and has less tendency to contract. The late John Anderson (9), whose brilliant pioneer work in the electrosurgery of the breast is well known, was assured by his anæsthetist that a very much lighter anæsthesia suffices than for the scalpel operation, and my anæsthetist confirms this.

The *disadvantages* of electrosurgery are that high-frequency machines of sufficient power to prove effective in all branches of surgical work are cumbersome and difficult of transport, and at present are undoubtedly expensive initially, though not in their running costs. Some considerable period of training is required for their effective use since a very different touch is needed than for scalpel surgery. Also ether, acetylene, or other similar explosive anæsthetic cannot be employed in operations upon the head or neck.

### Indications

Undoubtedly the most important indication for electrosurgery is to replace the scalpel in operations for the removal of malignant growths, whether of the skin or of the deeper tissue or organs ; here, by sealing off divided lymph vessels, by destroying exposed cancer cells and, as some believe, by the selective action upon malignant cells of the heat generated, it minimises the chances of local recurrence. The radical removal of breast carcinoma is one of the most frequently performed electrosurgical operations and its description will serve as a type for similar procedures elsewhere in malignant disease. In this operation the large " indifferent " electrode is applied to one of the legs or to the opposite arm. If, as the final act of skin preparation, an alcoholic or ethereal solution of iodine or other antiseptic be applied, time must be allowed for this to evaporate completely, as otherwise an explosive mixture may lie immediately above the skin. The skin incision is made by quick and light strokes of the electrosector held like a pen and fitted with the thinner (0·005) tungsten wire. Any one of the classical incisions may be employed, that most frequently adopted being a circle, 5 to 6 in. in diameter with the growth as its centre, with an axillary extension along the anterior axillary fold to the upper third of the arm, and a downward extension almost to the umbilicus.

Only the skin is divided with the 0·005 wire, the thicker (0·008) being used during the rest of the operation. The current requires to be increased for the division of the resistant subcutaneous fat, and this is incised to a depth of ½ in. along the whole incision. Any spurting vessels are seized with artery forceps and coagulated by touching the forceps for a few seconds with the electrosector charged with the coagulating current. Towel clip-forceps are attached to the edges of the skin at a few appropriate points; these are left on throughout the operation and serve usefully as retractors. The skin is now undermined in the plane of the subcutaneous fat, leaving about ⅓ in. of fat on the under aspect of the skin to ensure its nourishment, and taking particular care to avoid button-holing the flaps. This undermining is accomplished by swift strokes of the electrode and is continued to the clavicle above, to 1 in. across the midline internally, almost to the umbilicus below, and externally to 1 in. behind the anterior edge of the latissimus dorsi. The axilla is opened by dividing the attachments of the pectoralis major to the clavicle and humerus, the pectoralis minor at its insertion into the coracoid process, and the costo-coracoid membrane; for the division of the muscular tissue the current is reduced in strength so as to avoid unpleasant contractions. The electrosector is temporarily laid aside while the axillary vessels and nerves are cleaned of all fat and glands, this being accomplished with a blunt dissector or a dissecting forceps in the right hand and the left forefinger wrapped in gauze; Howard Kelly's metal rake is also useful for this purpose. This stripping is commenced above at the inner edge of the first rib and is continued downwards along the axillary vessels and nerves into the arm. The branches of the main vessels are doubly clamped with artery forceps as they are exposed, divided between the forceps with the cutting current and their proximal ends ligatured. The long subscapular and the posterior scapular nerves are exposed and stripped clean of fat up to their entrance into the latissimus dorsi and serratus magnus muscles respectively, and the fascia is stripped from these muscles with the gauze-covered left forefinger; the intercosto-humeral nerve may also be stripped and saved unless it passes dangerously near any mass of secondary axillary glands, in which event it should be divided proximally and distally to the mass with the cutting current and the intervening portion left to be removed along with the rest of the axillary contents. The cleared axilla is loosely packed with a warm saline pad while the large mass consisting of the breast and overlying skin, deep fascia, pectoral muscles, and axillary contents is separated with the electrosector internally from the sternum and costal cartilages, below from the rectus abdominis muscle, taking with it the anterior rectal sheath, and externally from the external oblique muscle and underlying ribs and from the anterior portion of the latissimus dorsi. It is now lifted gently away from the chest wall and its deep connections separated: these consist of the costal attachments of the pectoralis minor, which are divided close to the ribs, and the fascia over the serratus magnus, which is dissected from the muscle with the electrosector, taking a thin shaving of muscle along with it. All vessels which have been seized are now coagulated as previously described, a stab wound is made with the cutting current in the base of the axillary flap, and a drainage tube introduced through it into the axillary space. The edges of the wound are approximated with interrupted sutures, any tension being relieved by the insertion of two or three mattress sutures placed some distance away from the margins of the skin. It may be impossible, without unjustifiable tension, to close the central portion of the wound, but, owing to the free undermining of the skin in all directions, it very rarely indeed happens that sufficient remains unclosed to require skin grafting either at the time or later.

The operative treatment of non-malignant conditions opens up a wide field for electrosurgery, and I have employed electrosection in most of the operations that fall to the lot of a surgeon to a large general hospital. The space at my disposal does not permit reference to more than a few examples. All operations in which incisions have to be made into tissues already infected are more safely undertaken with electrosection than with the scalpel. With the exception of the division of the bone every step of an amputation can be performed with electrosection, the main vessels alone requiring ligature ; perfect primary union can result with much less tendency to a painful stump.

In dividing the abdominal wall during paramedian laparotomy, after division of the skin the current requires to be increased considerably for the severance of the subcutaneous fat, and afterwards reduced for that of the anterior sheath of the rectus so as to avoid inconvenient contractions of the underlying muscle ; the inner edge of the rectus is then retracted outwards and the peritoneum, picked up with two Spencer-Wells forceps applied transversely, is divided between them in a vertical direction sufficiently to admit two fingers of the left hand ; these raise the peritoneum away from the viscera and permit its safe and rapid electrosection for the full extent of the wound. All incisions of the hollow viscera—in resections, anastomoses " ostomies," and local excisions of ulcers or growths—are made with the electrosector, as are partial excisions of the solid viscera—liver, spleen, pancreas, kidney—while with it adhesions in situations difficult of access can be dealt with more readily than with knife or scissors.

In appendicectomy the base of the appendix is crushed with two closely applied Spencer-Wells forceps, the proximal of which is removed, a fine ligature applied just where the crushed portion joins the cæcum, the crushed portion cut across with the electrosector distal to the ligature and the stump invaginated into the cæcal wall by purse-string suture.

In cholecystectomy it is sometimes difficult to dissect the gall-bladder from the liver to which it has become firmly adherent. Here the cystic duct should be exposed first, and after its junction with the common bile duct has been clearly defined it is doubly clamped ¼ in. away from the common duct, divided between the clamps with the cutting current, the stump ligated with catgut and, if possible, buried by suturing over it any adjacent fatty tissue available : the cystic vessels are similarly treated. The clamp on the cystic duct is used to raise the gall-bladder from the liver, from which it is then detached with the electrosector, sufficient of its peritoneal coat being, if possible, preserved to be sutured over the raw surface of the liver after any bleeding points thereon have been coagulated. In markedly inflamed or sclerotic gall-bladders Whittaker (11) recommends a modification of Thorek's (12) operation of cholecystelectrocoagulectomy ; after carefully packing away the viscera, the gall-bladder is aspirated and is then split longitudinally with the cutting current up to the cystic duct. Calculi and fluid contents are removed by spoon and aspirator, and with the electrosector the gall-bladder is cut away about 1 cm. from its attachment to the liver, any bleeding vessels being ligatured. The portion of the gall-bladder adherent to the liver is not removed but its mucosa is destroyed by the application over its entire surface of a flat electrode charged with the coagulating current. If the cystic duct can be readily located it is ligated or drained, as indicated ; if not, it is ignored. Drainage is established and omentum is packed in to prevent adhesions to other viscera. In choledochotomy the common duct is incised longitudinally with the electrosector in its supraduodenal portion, preferably by cutting directly on to a contained calculus ; failing this the duct is lifted forwards by two fine pince-forceps applied transversely and is divided between these longitudinally.

In suprapubic prostatectomy by the "open" method of Freyer, the mucosa can be readily incised with the electrosector in circular fashion around the vesical orifice of the urethra before commencing enucleation, thus leaving a smooth mucosal edge instead of a torn and ragged one ; with it the "prostatic shelf" can be divided or, better still, a V-shaped portion removed therefrom, while the coagulating current can be easily applied to any bleeding point in the prostatic bed. In the per-urethral resection of the prostate with the McCarthy prostatic electrotome or one of its modifications, if the cutting current from a triode valve apparatus be employed the loop must be drawn through the projecting prostatic tissue more slowly than when incising skin owing to the comparatively slight coagulating action of the undamped wave current; otherwise the oozing of blood from the raw prostatic surface exposed may prove rather troublesome. In other genito-urinary operations—amputation of the penis, radical cure of hydrocele, epididymectomy—the knife can, with benefit, be replaced entirely by the electrosector.

In thyroid gland surgery also, particularly in the presence of hyperthyroidism, the electrosector can replace the scalpel throughout. Division of the skin with the very fine (0·005) tungsten wire as the active electrode can, I am convinced, leave a scar at least as inconspicuous as that after scalpel incision. The gland tissue can be readily severed and any spurting vessels coagulated, while it is sometimes preferable to scoop out, with the tungsten wire loop as the active electrode, the main mass of each lateral lobe, carefully avoiding the vicinity of the recurrent laryngeal nerves; this leaves a mere shell of thyroid tissue, and the cavity thus remaining can be obliterated by catgut suture.

It is in the electrosurgical treatment of such minor affections of the anal canal as polypi, fissures, fistulæ, and hæmorrhoids that is noticeable, more markedly, perhaps, than elsewhere, the remarkable diminution in post-operative pain as compared with that after the more usual surgical procedures; its application is here invaluable and I have completely discarded the knife and scissors in ano-rectal surgery.

Finally, from the point of view of the surgeon himself, electrosection will revive his interest in surgical procedures which, owing to the systematisation and standardisation of their technique, have become almost monotonous in their performance; even such simple operations as the excision of a sebaceous cyst or of a chronically inflamed bursa acquire, with electrosurgery, a fascination of their own.

## REFERENCES

1. Ellis, J. D. *Arch. of Surg.*, 1933, xxvi., 981.
2. Pearse, H. E., and Ward, G. E. *Amer. Jour. Surg.*, 1930, x., 540.
3. Smith, B. C. *Arch. Phys. Ther.*, 1931, xii., 474.
4. Lilienthal, H. *Ann. of Surg.*, 1933, xliii., 1594.
5. Jellinek, S. *Wien. klin. Woch.*, 1930, xliii., 1594.
6. Oudin (cited by P. F. Lowry). *Amer. Jour. Phys. Therap.*, 1931, vii., 489.
7. McLean, A. J. *Amer. Jour. Surg.*, 1932, xviii., 417.
8. Kelly, H. A. *Surg. Gyn., and Obst.*, 1931, lii., 502.
9. Anderson, J. *Brit. Jour. Surg.*, 1928, xv., 504.
10. Whittaker. *New England Journal of Medicine*, 1935, ccxiii., 13 and 14.
11. Thorek. *Jour. Amer. Med. Assoc.*, 103 : 169, July 21, 1934.

## CHAPTER XL

# TREATMENT OF GROWTHS AND OTHER ABNORMALITIES OF THE SKIN BY THE SURGICAL ELECTROTHERMIC METHODS

ELECTROCOAGULATION and electrodesiccation are of value in the treatment of malignant disease of the skin. The writer's preference is for the first-named method. They are also of value in cases of non-malignant growths and other abnormalities such as papillomata, warts, pigmented and non-pigmented moles, pigmented areas of skin, certain forms of nævus vascularis, telangiectasis, hypertrichosis and lupus vulgaris. For the treatment of most of these the method which the writer prefers is electrodesiccation, although good results may be obtained after electrocoagulation.

### 1. NON-MALIGNANT ABNORMALITIES

### Papilloma

Electrodesiccation is an excellent form of treatment for simple papillomata of the skin. The passage of the sparks reduces the tissue to a small hard dry mass. A little effort will then dislodge it. The patient shown in Fig. 133 had a papilloma on her temple measuring ¼ in. by ⅜ in. at its base and projecting ¼ in. from the surface. It was treated by electrodesiccation. Three months later nothing abnormal was visible (Fig. 134).

### Senile Warts

So-called senile warts, if small, can be destroyed usually by one momentary application of the sparks. Fig. 135 shows a case before treatment.

The patient was a girl of ten. The warts were on the left

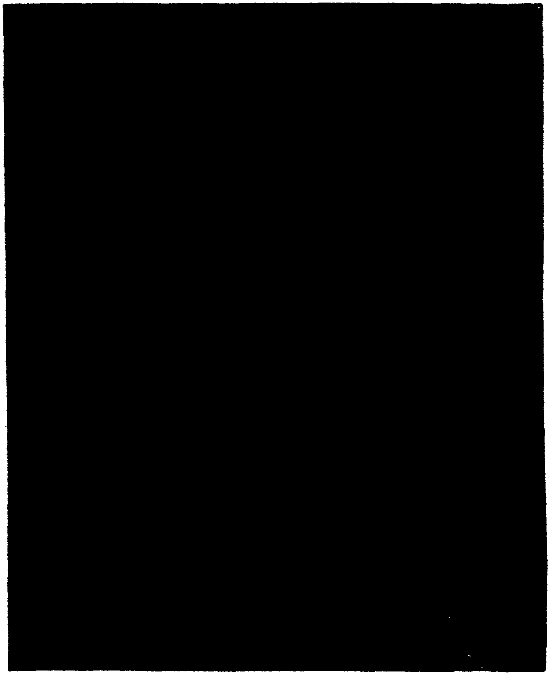

FIG. 133.—Papilloma on Left Temple.

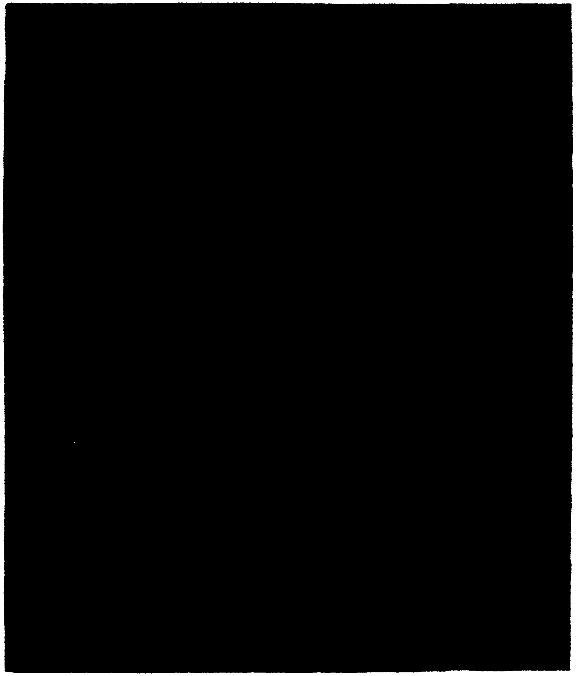

FIG. 134.—Same case as that shown in Fig. 133. After removal of Papilloma by Electrodesiccation.

side of the neck and varied in size from a currant to a pin's head.

Fig. 136 shows the result. This figure is on a larger scale than the preceding. The arrows indicate the position of the residual scars, which are scarcely visible. No anæsthetic was used for this case.

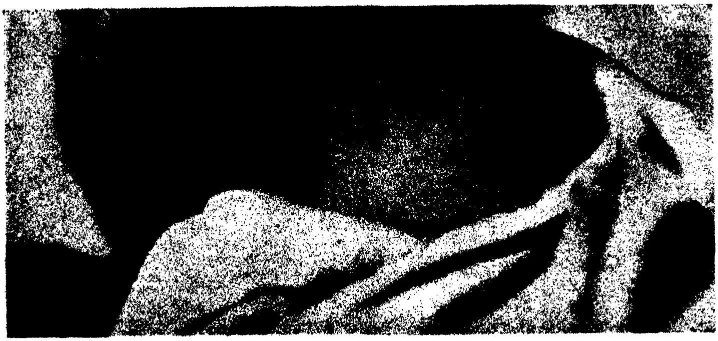

Fig. 135.—Senile Warts.

Fig. 136.—Same case as that shown in Fig. 135. After removal of Senile Warts by Electrodesiccation.

### Warts

These can be easily destroyed, whatever their size, by desiccation. This treatment is successful for flat warts as

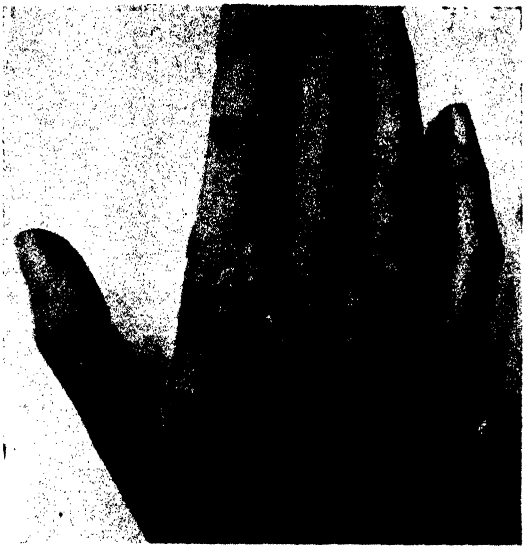

FIG. 137.—Warts on back of Fingers and Hand.

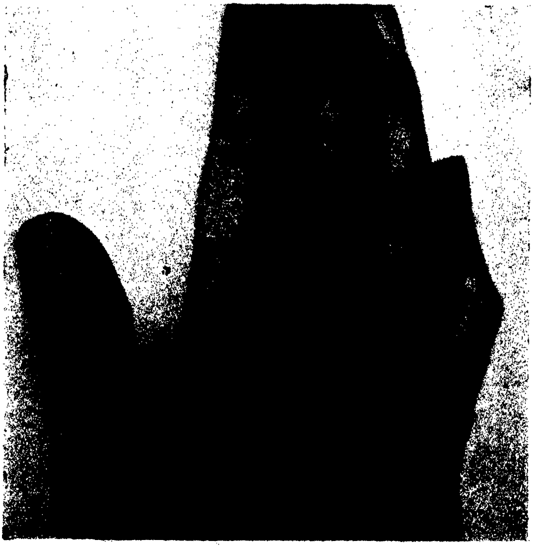

FIG. 138.—Same case as that shown in Fig. 137, after treatment by Electrodesiccation.

well as those which are pedunculated, although the latter can be as effectively removed by the zinc needle and electrolysis. The writer has found desiccation effective in destroying warts which have resisted every other form of treatment, and they have not reappeared.

Fig. 137 shows the warts on the hand of a girl of twenty-two. Fig. 138 shows the result after desiccation by sparks from the diathermy machine and subsequent healing.

## Pigmented Areas of Skin

These can be treated either by electrodesiccation or by diathermic coagulation, or the two methods may be combined. The first mentioned will be considered here.

A local anæsthetic may be given, but many adult patients can tolerate the operation without it, especially if very short sparks are used in the initial stage. A thin superficial layer is desiccated first. The sparks then are slightly lengthened and the desiccation repeated so as to dry the tissue to a little greater depth. The process is repeated and the sparks may ultimately be lengthened to about ⅛ in. The desiccation must be conducted evenly over the entire area, each portion receiving the same length of treatment. The desiccated layer may then be separated with the end of a scalpel, using the blunt edge.

The local reaction is slight. The scab that forms acts as a dressing. It should be bathed frequently in hot boracic solution. If there should be much swelling the edge should be raised from time to time to allow the escape of any exudation that may have collected. Ultimately the scab separates and reveals a smooth unwrinkled scar.

The scar must be inspected every three or four months, because specks of pigment may reappear here and there. It is difficult, even after long practice, to remove the pigment from a large area at one sitting. The recurrent spots should be desiccated again. Repetition of the treatment does not make the scar hard.

In Fig. 139 is shown a slightly raised hairy pigmented area, dark brown in colour, in a boy of eight. Different portions were treated on different occasions, some by desiccation and others by coagulation. The first operation was conducted in July, 1920. In February, 1921, it was seen that small spots of pigment had reappeared in the scars which formed in the desiccated areas. These were then coagulated. Fig. 140 shows the appearance in May, 1921. The scar was pink and there was a slightly raised hard ridge at the lower edge ; elsewhere it was soft. This case was shown at the meeting of the Section of Electrology of the Anglo-Franco-Belgian Congress held in London in 1922. The scar was described in the French Report as "assez souple." It was again shown at a meeting of the British Institute of Radiology at St. Bartholomew's Hospital in February, 1926. The scar was soft and there was no pigment.

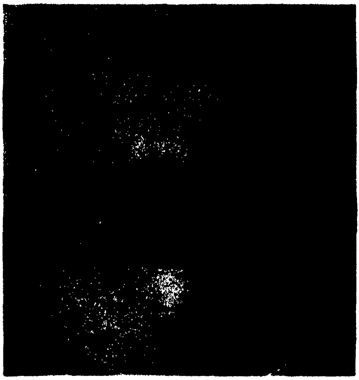

FIG. 139.—Pigmented Mole.

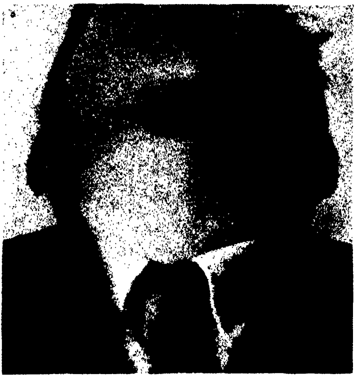

FIG. 140.—Same case as that shown in Fig. 139, after treatment, in part by Electrodesiccation, in part by Electrocoagulation.

Fig. 141 illustrates a case of multiple black papillomata in a boy aged three and a half. The papillomata were very numerous and closely set together. They were treated by desiccation, the patient being under general anæsthesia, on November 24th, 1922. On January 19th, 1923, the region formerly occupied by the papillomata showed an erythematous scar containing a few spots of black pigment. These were treated by the same method. In November, 1923, the appearance was that shown in Fig. 142. The scar was free from pigment except in a small spot near the centre. The spot was treated by fulguration. On February 19th, 1926, the scar was pale and soft. A few specks of pigment were seen. (The dark appearance of the scar shown in Fig. 142 was due to erythema.)

It is only by long practice that the operator can learn to judge correctly the depth to which desiccation occurs during the operation when he is treating pigmented areas of skin. If he desiccates too superficially the pigmentation will reappear in the scar. If he desiccates too deeply the scar will retain its pale appearance but its site will be unduly depressed. A slight depression will always remain, however skilfully the operation is performed. This fact should be told to the patient before the operation is considered. The depression does not grow deeper in course of time.

FIG. 141.—Closely-set Black Papillomata.

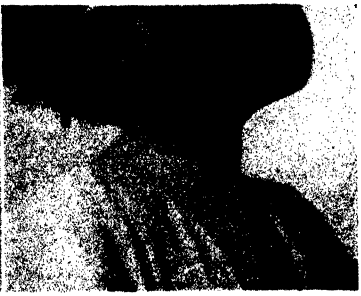

FIG. 142.—Same case as that shown in Fig. 141, after treatment by Electrodesiccation.

## Clavus (Corn)

Cases of very painful corn sometimes find their way to the practitioner of electrotherapy after unsuccessful trial of various methods of treatment. They can be removed by desiccation, but the treatment must be very thorough. Small corns may be rendered anæsthetic by spraying them with ethyl chloride. As the anæsthesia lasts only for a very short time it is advisable to use long sparks and direct them quickly over the entire area. It may be necessary, when sensation returns, again to freeze the desiccated part and make another application of the sparks.

When the corns are large it is usually necessary to inject novocaine and adrenalin after freezing with ethyl chloride.

After the desiccation is complete an attempt to remove the dried portion may cause bleeding. It is better, therefore, to cut or scrape away the superficial layers and instruct the patient to soak the foot in hot water as frequently as possible so as to assist the separation of the desiccated tissue that remains. If pain develops during the process of separation, it can be alleviated by detaching the dried tissue, wholly or in part, by means of a scalpel.

In cases where the corns are large and very painful it is necessary to adopt the additional treatment above described. Otherwise the patient will suffer continuous pain.

One of the most severe and intractable cases in the writer's experience was that of an elderly lady, a patient of Dr. Maltby. A hard horny mass projected from the end of the little toe. The patient had suffered much pain for two years and she was unable to walk far. The toe was very tender to the touch. The corn had been treated by cutting, by plasters and by "electricity."

Before commencing the electrodesiccation a narrow elastic band was gradually tightened around the base of the toe. Anæsthetic was injected under the skin beyond the band. The corn was thoroughly desiccated and after removing the band the patient was instructed to soak the foot frequently in hot water each day. Ten days later the corn had disappeared and healing was nearly complete.

### Nævus (Angioma)

Electrodesiccation is a rapid and efficient form of treatment for certain forms of nævus. When the constituent vessels are not close to each other, treatment by the galvanic current (electrochemical cauterisation) is a slow process. Electrodesiccation instantly obliterates the vessels and a scarcely perceptible mark is left. The sparks can be regulated so as to confine their action to the spot desired. They dry the tissue and do not burn it like the galvano-thermocautery.

Electrodesiccation is equally successful for telangiectases, and the cosmetic results are excellent.

In the treatment of cavernous angiomata of the skin the galvanic should be employed in preference to the diathermic current or desiccating sparks. The overlying skin is sacrificed during the operation when the two last mentioned are employed, and very strong currents or thick sparks are needed if the angioma is not small in size.

In a few cases, however, electrodesiccation is a most efficient method of treatment. This was demonstrated in the following cases.

A medical man visited the electrical department of St. Bartholomew's Hospital and said that he had a pulsating nævus on the side of his nose. An attempt had been made abroad to treat it by the galvanic current and the blood spurted from it after the needle had been withdrawn. The nævus measured ¼ in. by ⅛ in., and it projected about ⅛ in. above the surface. It was covered by normal skin. Electrodesiccation was administered on three occasions, one-third being treated per séance. The final result of the treatment was a slightly depressed scar which marked the site of the original nævus.

Electrodesiccation was successful, in addition, in the case of a nævus of the left *ala nasi* of an elderly lady. In appearance and size it resembled a red currant and slight pulsation could be felt in it. Free bleeding had occurred at intervals. For this reason it was deemed unsafe to utilise the galvanic current. Electrodesiccation was administered. Two séances of treatment were required to obliterate the nævus.

Electrodesiccation was equally successful in two similar cases. In one of these the nævus was on the bridge of the nose. In the other it was on the right cheek over the malar bone.

In treating cases of this kind the needle electrode used for the electrodesiccation should on no occasion touch the nævus. If this precaution is not taken there will be a likelihood of the adherence of particles of tissue to the point of the needle ; when the latter is removed the tissue will come away with it and bleeding will occur.

### Lupus Vulgaris

The use of diathermy for the destruction of lupus was originally described by Nagelschmidt in 1910 (*Zeitschr. f. ärztl. Fortbild.*, 1910, No. 24). In his "Lehrbuch" illustrations are shown of 6 cases before treatment, and after treatment and subsequent healing ("Lehrbuch der Diathermie," 1st edition, pp. 298–303).

In one case there were several nodules behind the ears, and on the cheeks of both sides and under the chin. One application of diathermy was made under general anæsthesia. After healing, a smooth scar was left, and it is stated that there was no reappearance of lupus. Judging by the photograph, the result was excellent.

In another case there were lupus nodules on the right cheek, inside and outside the nose, fistulæ, and abscesses at the edge of the mandible. The same case, four years after treatment by diathermy, showed scars in the site of the original disease and no apparent nodules. In another case, tuberculosis had affected the skin and bone of the thumb. In spite of amputation, there was recurrence on the stump and the skin of the hand. The lesions were destroyed by one application of diathermy and no recurrence was noted as late as four years after.

Details of the cases and of the method of applying the diathermy are not give in the "Lehrbuch."

Since 1919 the writer has employed electrocoagulation or electrodesiccation in the treatment of a few cases of very long duration which had resisted other local therapeutic measures or had improved up to a certain stage without complete disappearance of the lupus nodules. In some of the cases the disease had been in existence for years ; the patients had had courses of treatment elsewhere from time to time and ultimately were sent for a trial of "electrical" treatment. Electrothermic treatment caused the disappearance of a number of the nodules and their replacement by soft non-contracting cicatricial tissue. There was no evidence of return of lupus in the scars. Results of this kind were more easy to obtain in the treatment of the nodules which had more recently appeared and they were procured without the help of general ultra-violet ray therapy. Greater difficulty was experienced, however, in the electrothermic treatment of nodules in scar tissue which had persisted for many years. Frequent repetition of the treatment was often necessary. In these cases it was found that general irradiation with ultra-violet light, in combination with the local diathermic treatment, was more efficient than the last mentioned by itself.

It is difficult, therefore, to assess the value of electrothermic treatment of lupus vulgaris and compare it with local treatment by chemical caustics, *local* irradiation, etc. The fact that the diathermic current can coagulate tissue *en masse*, seal the lymphatics and small blood vessels and kill the infecting organisms should render advisable a wider trial of the method, especially in the long-lasting and intractable cases which are still encountered.

### *Treatment*

The nodules may be treated either by coagulation or by desiccation. The local reaction after desiccation is less than that after coagulation, and the healing is quicker. On the other hand, there is less likelihood of particles of tissue escaping destruction when the diathermic current is used to coagulate than when electrodesiccation is practised. In adults, the last mentioned can usually be practised without an anæsthetic, local or general, if the nodules are not large. Coagulation, as a rule, cannot be practised thoroughly unless an anæsthetic is administered. In actual practice desiccation should be tried first.

Large nodules may require two or more applications of treatment. In these cases it is sometimes found that the scar which replaces the originally infected tissue is not entirely free from lupus. Minute nodules are sometimes seen, too, in the skin around the scar. Repetition of the treatment is then necessary until all the nodules disappear. Repetition of the treatment does not alter the final appearance of the scar.

The cosmetic results are excellent, both after coagulation and desiccation. Soft smooth scars are left. Keloid may develop in the scar. It may be prevented by applying pyrogallic ointment to the ulcer after the coagulated or desiccated tissue has separated.

Ultra-violet light is a valuable ally to diathermy in the treatment of lupus. It accelerates healing of the wounds left after destruction of the nodules and increases the natural therapeutic powers of the body. Although general irradiation is not essential when there is no evidence of the disease in parts other than the skin, it is always helpful, especially in long-standing cases where lupus is present in old scar tissue, and it is necessary when the disease exists also in regions inaccessible for electrothermic treatment.

A good example of the value of electrothermic treatment in combination with general ultra-violet ray treatment is seen in the following case.

The patient, a boy of 6, had several nodules of lupus in the cheek, side of nose, upper eyelid and eyebrow, with secondary infection of the skin. He was sent to the electrical department of St. Bartholomew's Hospital by Dr. Adamson, under whose care he had been in the dermatological department.

Ultra-violet rays from a tungsten arc lamp soon removed the secondary infection, but had no effect on the lupus. The patient was then given a general anæsthetic and some of the nodules were treated by diathermy, some being coagulated, others desiccated. After healing of the wounds some fresh nodules were seen around some of the scars. The operation was repeated and some more of the original nodules were treated as well as the new ones. The operation was again repeated on a third occasion. In the hope of avoiding further operations the patient was subjected to local and general ultra-violet light treatment. The patient improved rapidly under the additional treatment.

Below are given the particulars of 3 cases which have been kept under observation for the longest periods. The case first described (A. R.) is the first example of lupus vulgaris which the writer treated by diathermic coagulation. There was evidence of the disease in the nasal passages. No ultra-violet ray treatment was administered.

A. R., female, aged 40. A number of nodules were present in the skin over the right maxilla. They had been treated for a long period by ultra-violet rays from a tungsten arc lamp. No apparent difference was observed. On February 11th, 1919, one of the nodules was coagulated by diathermy. A single needle electrode was passed into the centre and the current very slowly increased until the coagulation reached the boundary of the nodule. The coagulated tissue sloughed away, leaving a small ulcer, which healed after ten days. The remaining nodules were treated in a similar manner at later dates in the same year (March 28th, May 27th, June 24th, October 14th). After healing there remained smooth scars. A patch of keloid developed on the scar left after the first ulcer had healed, but not on the other scars.

On April 6th, 1920, the scars appeared healthy, but a fresh nodule was present. This was treated in the same way.

On September 9th, 1921, four minute nodules were apparent at the periphery of the region formerly affected. These were treated by electrodesiccation. The patient reported at intervals during the succeeding years. She was last seen in 1935. During the period of fourteen years she reappeared from time to time. Fresh nodules were usually found. They were treated by desiccation.

M. J., female. This patient first came under the author's care in January, 1919, when she was 15 years old. There was a nodule of lupus measuring ¼ in. in diameter on the right shoulder. There were also groups of smaller nodules in the skin over the right wrist, the lower part of the left deltoid and the right side of the nose and adjoining part of the cheek. Treatment by X-rays had been given at long intervals over a period of two years and some improvement had been effected. She was then sent to the writer for local treatment by ultra-violet light. The affected areas were submitted to radiation from the tungsten arc lamp, after application of salicylic acid plasters. The single nodule on the right shoulder, however, was excluded from the treatment until August, 1919, when it was subjected to diathermic coagulation, under local anæsthesia. A single needle electrode was used, the nodule and surrounding skin for a short distance were coagulated. After healing there was a soft scar which remained free from re-infection.

Local treatment of the remaining nodules by ultra-violet light (from a tungsten lamp) was continued. Progress was made, but very slowly. From time to time a nodule was selected from one or another of the groups and treated by diathermic coagulation or desiccation. These nodules had the benefit of both forms of treatment, and the disease disappeared much more quickly than was the case with the nodules that received the ultra-violet rays alone. Healing occupied from two to three weeks.

In 1927 treatment by *general* irradiation was commenced and from time to time a nodule was desiccated. The patient began to make more rapid progress and her general health showed great improvement. In 1929 she appeared to be free from lupus. In 1930 a minute nodule was seen on the wrist. It was treated by desiccation.

This patient was last seen in 1935. There was no evidence of lupus and the scars were soft and not contracted.

C. P., male, aged 39. This patient had had lupus in the skin of his left shoulder since early boyhood. Various forms of treatment had been given from time to time. He consulted the writer because a fresh series of nodules had recently appeared.

The part affected was the skin of the shoulder and the posterior part of the upper arm to about 2 in. from the olecranon. There was much scar tissue and a number of nodules of lupus in the skin of the shoulder. Slightly elevated, scab-covered areas and lupus nodules were present in the skin of the middle third of the arm. Beyond this part the skin was smooth but a number of nodules were visible. These had recently appeared.

The fresh nodules were treated by electrodesiccation. The last one was treated in 1928. At the present time (July, 1936) the scars are smooth, soft and not contracted and there is no evidence of lupus in them.

Similar treatment was given to the nodules elsewhere. The task was lengthy and arduous. Progress was not obvious until treatment by general ultra-violet light irradiation was given in addition to the desiccation. Courses of treatment were given from time to time.

The skin now is smooth and the major number of nodules have disappeared.

An interesting feature, since the commencement of the ultra-violet ray treatment, is the patient's almost complete immunity against "colds in the head." Originally he was never free from them, but he has had only one minor attack since he received his first ultra-violet ray treatment.

Tuberculous ulcers should be treated by diathermic coagulation. Healing will take place and soft scars will be left. Ulceration will probably reappear later on if the mucous membranes are infected and not subjected to treatment. It is a good plan, in these cases, to subject the patient to general irradiation with ultra-violet rays. The following case of tuberculous ulcer was treated by diathermy and remained healed for long periods, although the ulceration reappeared at later dates. General irradiation was not practised in this case.

Mrs. B., aged 74. The ulcer was situated on the tip of the nose. It measured ½ in. in diameter, and was covered by a thick dry scab. It was coagulated by diathermy on April 8th, 1921. It healed and a healthy scar was left. Two years later a small superficial ulcer was seen at the centre of the scar. It was treated by concentrating ultra-violet rays upon it. It did not heal, and on November 20th, 1923, it measured ¾ in. by ¼ in. It was then treated by diathermic coagulation and again healed. In March, 1925, ulceration was again seen; in addition there were two small ulcers, one on each cheek. All were treated by diathermic coagulation. In December, 1926, no ulceration was evident. Erythematous scars were present.

Considerable experience in the treatment of lupus by diathermy was obtained by Dr. A. E. Milner. He employed the operation of fulguration and preferred to treat the patient under general anæsthesia. Up to January, 1924, he had treated 60 cases. Cures were obtained in 42 cases. One operation only was necessary in 5 cases. Two operations were needed in 5 cases. The average number of operations performed on the cured cases was 3·5.

Dr. Milner's cases included those in which the mucous membranes were infected as well as the skin. Re-infection of the latter is likely to take place unless the former are subjected to diathermy. The situation of the infected mucous membrane may render diathermy impossible. Dr. Milner did not undertake the treatment of cases unless every part of the diseased surface was accessible to fulguration.

### Lupus Erythematosus

Some cases of this intractable disease have been treated by Professor Bordier, of Lyons, by diathermic coagulation, and good results were claimed. The diseased skin was replaced by scar tissue and no recurrence was noted.

W. J. Harrison, of Newcastle-on-Tyne, treated a case by *medical* diathermy and good results were obtained. The case was in a lady, a private patient of the surgeon named. The disease had affected the skin of the nose and had resisted treatment by methods other than diathermy.

The active electrode was made of sheet lead. A gauze pad, soaked in strong salt solution, was placed over the affected area and covered by the lead electrode. At the first application of diathermy (February, 1921) the current was increased until the heat was the maximum which the patient could tolerate. The duration of the séance was thirty minutes.

Distinct improvement was noted when the patient came for her second treatment in May, 1921. At the second and subsequent applications the current was reduced because a small burn had followed the first treatment. Diathermy was repeated at monthly intervals. In September, 1921, the appearance of the skin was normal. In November, 1921, a small area showed recurrence. This disappeared under further treatment. Applications were made in November and December, 1921, and in January, February, March and May, 1922. During this period there were no visible signs of the disease, but the patient complained of slight pain and itching towards the end of the month following each application. She remained free from recurrence until January, 1923. During that year she was treated in January, February, March and November. In 1924 and 1925 she was given occasional treatment. In March, 1926, she was again treated. After this treatment she remained free from symptoms until June, 1927, when the premonitory symptoms of pain and itching reappeared. The appearance of the skin, however, was quite normal.

The difficulty in the way of treatment of lupus erythematosus by diathermy is that of measurement of the correct dose. Harrison employed 500 milliamperes at the first treatment; on subsequent occasions 150 to 200 milliamperes were generally used, and on no occasion more than 300. As the writer has insisted, earlier in the present work, the amperemeter is an unreliable guide to dosage. A thermometer in the pad under the electrode or a thermocouple would give more accurate information.

The writer is indebted to Mr. Harrison for the particulars of the case noted above.

## 2. MALIGNANT DISEASE

### Rodent Ulcer

Diathermy is a therapeutic agent of high value in the treatment of rodent ulcer. It has proved its worth, not only in early cases, but also in those which are more advanced, and in others which have resisted treatment by X-rays, radium, zinc ions or solid $CO_2$, or have recurred after temporary healing by one or another of these agents. The ulcers have healed, and smooth, soft, unwrinkled scars were left.

It is especially in cases in which cartilage or bone has been invaded that diathermy is of value. In cases of this kind, radium or X-rays are unable, in the experience of most workers, to destroy the malignant tissue. Diathermy, however, can destroy bone and cartilage just as easily as the soft tissues, and granulation tissue will grow over the site after the destroyed portion has separated.

Rodent ulcers of long duration in which a large amount of soft tissue and bone have been destroyed are difficult to arrest for long periods, although temporary healing can be effected. Recrudescent ulceration can again be treated by diathermy and healing will again occur. In this way the patient can be kept in comparative comfort and free from pain until death from asthenia occurs.

The author has treated, by diathermic coagulation, some cases of extensive rodent ulcer in which there was widespread destruction of skin and underlying tissues, and caries of bone. It is absolutely necessary, if any benefit is to be obtained from treatment by diathermy, that such cases should be seen not less frequently than once each month, and the treatment repeated directly recrudescence is seen or suspected. It is difficult to destroy all the malignant tissue at one operation, especially in regions where nearness of important structures compels cautious limitation of the diathermy.

After the first coägulation by diathermy, and the destruction of the edges and base, the ulcer is at first enlarged, but the raised, round, undermined edges disappear, and the borders of the ulcer assume a healthy appearance, and grow inwards. The size of the ulcer diminishes considerably and healing may occur, but recrudescence is very likely to take place and ulceration to recommence. Diathermy should then be reapplied without delay.

One of the cases which the author treated by diathermy had lost the front of the right cheek and the right half of the nose. The underlying bone had been extensively destroyed by the rodent ulceration, and a large cavity, bounded on the inner side by the nasal septum, connected the nasopharynx with the exterior. A gland, removed from the submaxillary region, showed the presence of carcinoma. The ulcer had been previously treated by caustics, and later by X-rays, and had been rendered quiescent, except at the outer edge, where a small mass of growth had appeared. This was coagulated by diathermy in June, 1917, under local anæsthesia, and healing followed.

The patient came under the writer's care again a year later. Active ulceration was taking place at the edges. Diathermy was applied, under general anæsthesia. After the sloughs had separated, apparent healing took place, and epithelium grew over the edges. The upper lip was reduced in size, in the region of the angle of the mouth, to a small rounded cord, ¼ in. thick, and a narrow area of healthy tissue separated the inner canthus of the left eye from the adjoining edge of the ulcer. Shortly after this operation excision of the right eye had to be performed. It was of extreme importance for the patient that the ulcer should not extend towards the left eye; also that the narrow bridge of tissue which connected the upper lip to the right cheek should be kept intact.

In January, 1919, diathermy had to be applied again to part of the outer edge, and in April, 1919, to the nasal edge. In July, 1919, recrudescence was observed at the outer edge and diathermy was applied. Apparent healing took place after each treatment. Up to the time of the last operation the patient had been able to travel and attend to his work. Pain was frequently felt, but applications of ultra-violet rays were very effective in procuring relief. The patient did not regain strength or activity after the last operation, and he died in September, 1919.

It seems, in this case, that diathermy delayed the progress of the malignant ulceration. During the patient's lifetime, the ulcer approached no nearer to the opposite eye, whilst the small shred of tissue, which was all that was left of the upper lip in the region of the angle of the mouth, remained intact to the end of the patient's life.

Dr. Gray, dermatologist to University College Hospital, has kindly allowed the writer to refer to this case, which had formerly been under his care.

A case which illustrates the power of diathermy to heal a carcinomatous rodent ulcer accompanied by destruction of bone and cartilage is described below. Radium and X-rays had failed to arrest the ulcer.

W. D., aged 39. This patient originally suffered from a rodent ulcer of the right cheek. It was treated by X-rays and healed temporarily. Afterwards it reappeared and gradually increased in size in spite of further treatment with X-rays and, later, with radium. On July 2nd, 1914, the ulcer had extended forwards on to the cheek, 1 in. in front of the external auditory meatus and backwards on to the pinna. Part of the latter had been destroyed.

On the day mentioned the base and edges of the ulcer were coagulated, including the eroded edge of the pinna and its cartilage, and the bone at the base of the ulcer. The patient was kept in hospital until healing was complete. Three months were occupied in the separation of the destroyed tissue and the subsequent healing. The latter process was certainly rendered possible and aided by the daily dressing and prevention of sepsis.

Four months after the operation the appearance was that depicted in Fig. 143. There was no ulceration or swelling, and the new anterior edge of the pinna had healed.

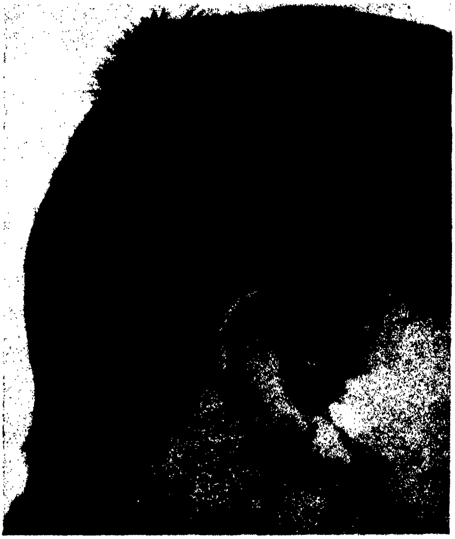
FIG. 143.—After treatment of Rodent Ulcer of Cheek and Pinna by Diathermic Coagulation.

An enlarged gland was then excised from the neck. It was found to contain carcinoma cells.

This patient was last seen nine months after the diathermy. There was then no sign of recrudescence. The subsequent fate was not ascertained.

Cases of rodent ulcer in which bone and cartilage have not been invaded can be healed by diathermy even if treatment by zinc ions and X-rays are without effect. In the case described below no recrudescence had occurred three and a half years after diathermy. An illustration of the ulcer before the treatment is shown in Fig. 144. Fig. 145 shows the appearance two and a quarter years later. The patient was last seen three and a half years after the treatment and the healing had remained perfect.

E. B., aged 64. This patient had had an ulcer in the left temporal region. An ulcer in this region had been noticed sixteen years previously. It had been treated by zinc ions by the late Dr. Lewis Jones and healed. In 1917 ulceration of the same region recommenced. X-ray treatment was applied and the ulcer healed partially. It then enlarged in spite of further treatment by X-rays (Fig. 144).

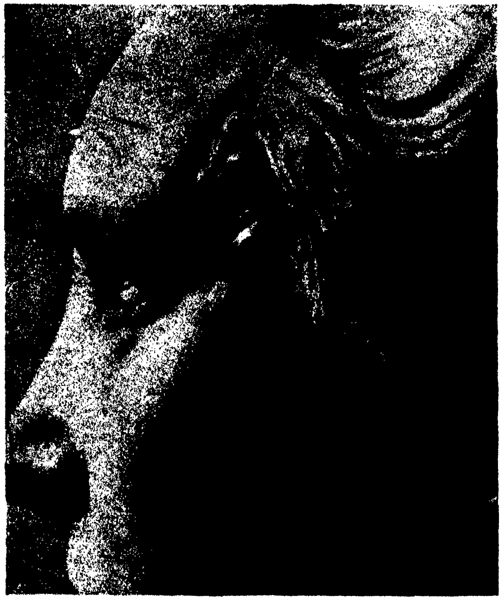

Fig. 144.—Rodent Ulcer, before treatment by Diathermic Coagulation.

In 1918 the edges and base were coagulated by diathermy, under general anæsthesia. The ulcer healed, but a small nodule was noted two months later at the upper edge of the scar. This was coagulated by diathermy under local anæsthesia. Healing followed and there was no reappearance of nodules or ulcers for fourteen months. A small superficial ulcer then appeared. This was coagulated by diathermy. No further treatment was required (Fig. 145).

A case of rodent ulcer which had been kept under observation for eight years and had required no repetition of diathermy is described below. The histological structure was that of rodent ulcer becoming carcinomatous. Treatment by zinc ions and X-rays had been ineffective.

S. S., aged 55. This patient had an ulcer measuring 1 in. by 1 in. on the right frontal region of the scalp. Its edges were raised and everted. Its histological structure was that of rodent ulcer becoming carcinomatous. Treatment by zinc ions and X-rays had proved ineffective. The chief symptom was incessant and severe pain.

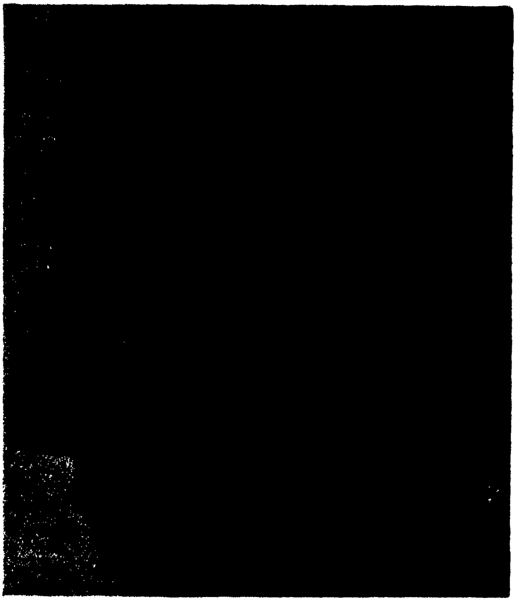

FIG. 145.—After treatment of Rodent Ulcer by Diathermic Coagulation. (Same patient as pictured in Fig. 144.)

The ulcer was coagulated by diathermy on April 14th, 1914. The pain was greatly relieved. The destroyed tissue sloughed away, leaving an area of bare bone measuring 1½ in. by 1⅛ in. In July, 1915, the area of bare bone had increased to 2 in. by 1⅜ in. The soft tissues at the edges were tender but not hard or infiltrated. Some pus was seen at the edges. The patient complained of "attacks of pain like neuralgia." She refused further treatment. In October, 1916, the condition was unchanged. In May, 1919, a plate-like piece of bone had apparently separated. It was easily removed manually, and a bony area measuring 1⅞ in. by 1 in. was uncovered. Dry scales were present at the edges. The soft tissues were dry and not infiltrated.

Fig. 146 shows the appearance of the region, formerly occupied by the ulcer, on May 30th, 1919.

On August 3rd, 1920, the patient wrote to say that she felt quite well and had had very little pain during the last year. She came to the hospital in September, 1920. The bare area of bone was then partly covered by scar tissue.

The author showed this case at a meeting of the Section of Surgery of the Royal Society of Medicine in April, 1922. The bare area of bone was then nearly completely covered by scar tissue. The patient died on January 16th, 1926, after a week's illness, due, according to the report, to bronchitis. It was stated that one spot of bare bone remained and that it had been painful for some months before the patient's death.

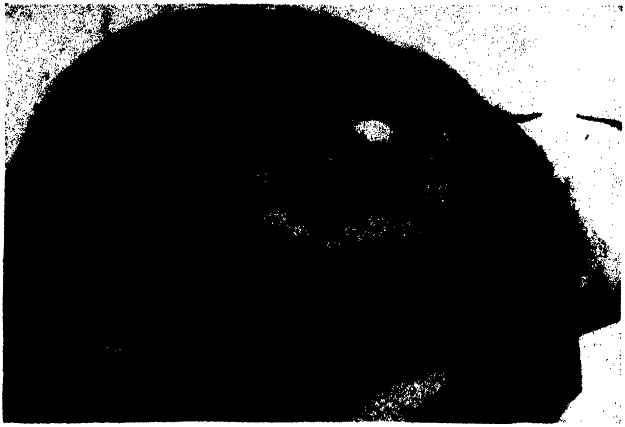

Fig. 146.—After Separation of Bone following Diathermic Coagulation of Rodent Ulcer of Scalp.

## Squamous-cell Carcinoma

Squamous-cell carcinomata of the skin are no less suitable for electrothermic methods of treatment than those of the basal-cell type (rodent ulcer). In its early stages the treatment by carbon-dioxide, radium or X-rays has its advocates and cures seem to have been effected. In advanced cases diathermic coagulation is more effective.

An interesting case is that of a gentleman who had an ulcer of his left cheek, measuring ⅝ in. by ¾ in. and about ¼ in. deep. Its edges were raised and hard. It had been first noticed about a year before. He stated that he had had a similar ulcer on his right cheek fifteen years ago, that it had been healed by the late Dr. Lewis Jones by means of zinc ions. In view of this the writer treated the ulcer on the left cheek by the same method, but without success. Diathermic coagulation was then effected (July 8th, 1920). Complete healing was not produced until another application of diathermy had been made (September 23rd, 1920). In December, 1920, the ulcer was completely healed. A ridge of keloid appeared in the scar. In July, 1921, there was no ulceration. The keloid had diminished and the scar tissue elsewhere was soft.

He died of old age in 1926, and his medical attendant told the writer that there had been no return of ulceration before death.

The case shown in Fig. 147 was one of slowly growing carcinoma of the skin in a woman of 63. A small " sore " had appeared on the front of the chest in 1913. It was treated by zinc ionisation and healing occurred. Later the sore reappeared and could not be made to heal under treatment by zinc ionisation or by X-rays. When the patient came under the writer's care, in September, 1922, there was a fungating mass of growth measuring 3½ in. by 4 in. The appearance was that shown in Fig. 147. Under general anæsthesia the growth was coagulated by diathermy. A month later the slough had separated. Healing commenced and was nearly complete at the end of November, 1922. A small area measuring 1 in. by ¾ in. refused to heal. It was treated by diathermic coagulation and healing occurred. Fig. 148 shows the appearance in July, 1923. A small scab-covered ulcer was present near the centre of the scar. It did not heal completely, and diathermy was reapplied in January, 1924. In July and December, 1924, small recru-

FIG. 147.—Carcinoma of Skin of Chest, before treatment by Diathermic Coagulation.

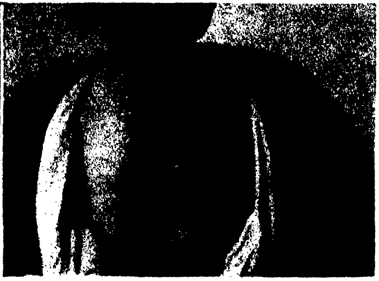

FIG. 148.—Same patient as pictured in Fig. 147. After treatment by Diathermic Coagulation.

descent ulcers were treated by the same method. In May, 1925, another small ulcer, which had reappeared, was subjected to diathermic coagulation. The major portion of the scar which replaced the tumour remained free from return of growth up to the present time (January, 1927).

The histological appearance of the growth was that of carcinoma.

### Epitheliomata developing in Scars

Good results have been obtained by various workers in the treatment of epitheliomata which have developed in scars. In the case described below a massive malignant growth was coagulated by diathermy. Healing occurred and there was no return seven years later.

J. C., male, was admitted to St. Bartholomew's Hospital on September 17th, 1919, when he was 48 years old, under the care of Mr. J. H. Roberts, surgeon to the hospital mentioned. When a child the patient received a large burn on the upper part of the right thigh and the adjacent part of the abdominal wall. Twelve months before admission an ulcer developed in the scar and increased in size. On examination, after admission, a large contracted scar was seen, and the hip could not be fully extended. A large fungating mass measuring 5 in. by 5 in. was seen in the right groin. It extended almost to the pubes. There was induration around. A section showed epithelioma.

On October 10th, 1919, the mass was coagulated by diathermy. On October 31st, and again on December 5th, 1919, some nodules which had escaped destruction were coagulated. On January 8th and March 3rd, 1920, skin from the left thigh was grafted on the wound.

On February 11th, 1927, the patient was well and the scar showed no signs of malignant growth.

The writer is indebted to Mr. Roberts for permission to publish this case.

### Roentgen-ray Keratoses and Epitheliomata

These appear to be particularly suitable for treatment by electrothermic methods. Professor Bordier,[1] of Lyons, treated some keratoses on his own fingers by diathermic coagulation. Permanent healing was the result. Another which was not treated became painful and an ulcer formed.

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[1] *Paris Med.*, 1922, XII., Part 2, 469.

The latter had the clinical characteristics of a malignant ulcer. It was treated in the same way. It healed in two months and there was no recurrence in two years.

G. E. Pfahler,[1] of Philadelphia, wrote that he had removed at least a hundred small keratoses from his own hands and that they had not reappeared. One was removed surgically in 1912 and shown to be malignant. Recurrence took place, but it was successfully treated by electrocoagulation.

### Lupus X-ray Epitheliomata

Coagulation by diathermy is a valuable method of treatment of epitheliomata which have developed in lupus after prolonged X-ray irradiation. Speaking on the subject at the Royal Society of Medicine on December 17th, 1926, H. H. Rayner said that cases could be satisfactorily treated by ordinary surgical measures in their early stages. In advanced cases diathermy gave better results, both in regard to economy in surgical interference and in respect of the ultimate result.

### Note on Treatment of Hypertrichosis by Electrocoagulation

Hair follicles can be destroyed much more quickly by the diathermic current than by the galvanic. From ten to sixty seconds are occupied in the destruction of each follicle when the galvanic current is used, whereas the diathermic current can achieve the same purpose in a couple of seconds, or even less. A fine platinum-iridium needle is used as the active electrode. When it is in position in the follicle the coagulation begins around the point of the needle. Hence, if the current is stopped at the correct moment, only the base of the follicle will be destroyed, and the epidermis will be spared. In this respect the diathermic method is superior to the galvanic, better cosmetic results being obtained. Considerable dexterity is needed for the purpose. It is essential that the diathermic machine should yield absolutely no current when the current regulator is at its zero position because a very small current is needed for the destruction of the minute amount of tissue around the hair bulb.

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[1] *Amer. Jour. of Roentgenology and Rad. Therap.*, N.Y., 1925, XIII. 41–48.

# CHAPTER XLI

# TREATMENT OF MALIGNANT DISEASE OF UPPER AIR PASSAGES

BY

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SINCE the day of Hippocrates, cauterisation has been employed for the treatment of tumours, and throat specialists especially have used it for many other conditions. In 1910 Dr. Lewis Jones invited Doctor Nagelschmidt to give a demonstration of surgical diathermy in the throat department at St. Bartholomew's Hospital. It was at once recognised that high-frequency currents had many advantages. If properly applied the treatment is absolutely safe. Although patients may complain of a feeling of faintness, sometimes associated with a fall of blood pressure, there is rarely any shock. On the contrary, the current seems to have a stimulating effect on the nervous system so that the patient is much fitter than when the same operation has been performed by cutting.

Usually the operation can be completed in a shorter time than with other methods. Growths, even those that are vascular, can be destroyed with much less loss of blood than with cutting. The absence of pain after this treatment is remarkable, owing to paralysis of the sensory nerves—even after operations in the mouth or throat patients may be able to swallow easily within a short time. It is also noticeable that inflammatory reactions are not nearly so severe as with simple burning, and that any sepsis or sloughing that results is of a harmless and innocent nature so that there is rarely any toxæmia with rise of temperature or pulse.

In addition to the above advantages there is the fact that the vessels and lymphatics are sealed by the coagulation. The immense importance of heat was not at first realised. In all malignant growths there is a virulent poison—almost certainly an ultra-microscopic virus—which may be present in great quantity. There can be little doubt that when a virulent growth is removed with the knife this poison enters the blood vessels and lymphatics and re-infects the wound, thus producing dissemination. As the late Professor Bloodgood expressed it, " If a malignant growth is cut into by the knife or curetted you might as well send for the undertaker."

The high-frequency currents produce such intense heat that the poison in the cells is immediately sterilised. With diathermy the heat extends far beyond the area of the operation, and with operations in the mouth it can be felt in the neck even as low as the clavicles in a decreasing degree. This may have a profound effect on the cells even at some distance from the growth that is destroyed.

For these and other reasons no throat department should be without a diathermic apparatus. For malignant growths this should be employed whenever possible. For biopsies the fragments should always be removed by electrosection in preference to any cutting instrument. The temptation to curette or to take growth out of deep pockets before it has been completely coagulated should be strongly resisted.

### Technique in Practice of Diathermic Coagulation

As Nagelschmidt pointed out, it is essential that the surgeon should understand, or have an assistant who is responsible for, the current. This must be of the proper strength to secure rapid or slow destruction of the tissues as required. For fear of burns the surgeon should wear rubber gloves. Except for small localised growths general anæsthesia is advisable. With local anæsthetics the patient must be warned of the danger of moving, which may easily result in sparking or burns. Ether must never be used or any explosive mixture. Some very serious accidents have been reported in the medical papers in which explosions have occurred, causing burns both to the surgeons and patients—in several instances with fatal results. As a rule an intratracheal tube should be passed and gas-oxygen-chloroform mixture given. A preliminary ligature of the external carotid or other arteries may be necessary in some cases, but it should be remembered that the wounds do not shed their sloughs and clean up quite so quickly when this has been done.

As Cumberbatch has shown, it is important to remember certain rules when operating on these regions. Care must be taken that the current is not turned on too frequently or for too long, especially when using the lower strengths, for fear of producing too much heat either locally or at a distance. This can be avoided by feeling the wound occasionally with the finger; or in certain situations when in the neighbourhood of important structures such as the large vessels or the eyes, larynx, etc., by swabbing the parts with sponges dipped in iced water. If necessary, two small electrodes can be used, which makes coagulation easier to control—a method favoured by Ohngren when operating on growths in the nasal sinuses. Complete control of the depth dose is impossible, but in skilled hands serious burns are extremely rare.

When hissing and bubbling commence—owing to escape of steam—it is a signal for stopping the current, and it should always be turned off when boiling of the fluids becomes vigorous. To avoid serious sparking with damage to normal parts the electrode must be kept in contact with the growth until the current is switched off.

The diathermic current can be used either to coagulate the abnormal tissue itself (see below, *Coagulation*), or to coagulate a layer of healthy tissue around and below the abnormal tissue (see below, *Circumvallation*), or to coagulate the abnormal tissue—the coagulated part then being excised (see below, *Coagulation followed by Excision*).

*Coagulation*. The electrode may be a small disc or button, or a single needle or group of needles. In many situations special insulation of the instrument, so that the needle can be pushed quickly in and out, is required. If a strong current is used the tissue close to the electrode is coagulated quickly, is rapidly dried and rendered non-conductive. Sparks appear and the diathermy ceases. On the other hand, a weak current coagulates slowly, drying is delayed and tissues at a greater depth become hot before sparks appear. This may be an advantage when it is doubtful how far the disease extends into the deeper tissues.

*Circumvallation.* This treatment was first advocated by Howard Kelly. Usually a fine needle is used and by repeated punctures the affected part is completely isolated, all vessels and lymphatics being sealed. The method is valuable when dealing with soft tissues such as the tongue. Afterwards the surface of the growth can be coagulated with a needle or button, and with a blade electrode the affected part can be safely excised.

*Coagulation followed by Excision.* In cases where there are active ulcers or great proliferation of the growths it is often advisable to coagulate the tissues very thoroughly and dry the surface before attempting to excise them. Growths on the tonsil, tongue and jaw are often treated in this manner.

*Electrodesiccation* (see Chapter XLII., p. 503). This treatment is usually employed after a malignant growth has been excised to dry the wound completely and cover it over with a thin layer of desiccated tissue. As the heat only penetrates a few millimetres it can safely be applied when close to important structures.

*Electrosection.* The method is very largely employed for removal of malignant growths. The details of the current employed are described on p. 373. For dissections a fine needle electrode is employed or a wire loop for excision of tissues. When the wire is in contact with the tissues a minute arc surrounds it, and if the wire is moved fairly quickly they are divided and split by the arc to any desired depth. When the electrode is moved quickly coagulation does not penetrate more than a fraction of a millimetre and very little tissue is destroyed beyond the incision.

In many cases the edges of the wound can be brought together and sutured, healing taking place by first intention. Some surgeons even remove glands in the neck which are in close contact with the carotid vessels without damaging their coats. Wyeth claims that dissections performed in this manner give better results than when done with the knife.

## Healing after High-frequency Currents

As already stated, any tissues that have been treated by desiccation or by the cutting current usually heal without sepsis, the surface remaining dry and coated with a dark brown crust. But after coagulation in any form there is an exudation of lymph, and in a day or two the parts destroyed are covered by thick membranous sloughs. The latter adhere firmly and usually cause very little local inflammation. Even when they are offensive and have pus under them they rarely cause pain or toxæmia, the temperature seldom rising above 99° F.

To prevent sepsis frequent mouth washes of Condy's fluid or peroxide of hydrogen should be used. For very offensive sloughs the best treatment is inhalation of oxygen, which makes them separate in a few days. The ulceration and sloughing usually begins to clear up in ten days, but the process may not be completed for weeks. When bone has been coagulated the sequestrum that results usually remains dry and aseptic, often is quite painless and may take many years to separate. One of my patients who was treated in 1912 still has a harmless sequestrum which has never loosened and which causes no unpleasant symptoms.

The rarity of shock at the time of the operation, or after it, has been commented on. I know of no instance of death from this cause.

*Complications* are rare. Serious sepsis seldom occurs either locally or at a distance unless a patient is in a bad condition or has very extensive disease invading the neck or the bones of the skull. Septic teeth should always be removed before operation.

Hæmorrhage during operation rarely causes any trouble. In many instances the treatment can be carried out almost bloodlessly and all the smaller vessels can be sealed by the cautery. Large veins or arteries should be ligatured. Before extensive operations on the jaw, the tongue, floor of the mouth or pharynx, it may be advisable to ligature the external carotid, the lingual or other arteries. Secondary hæmorrhage may occur at any time but unless an artery is involved it is usually slight and can be stopped by simple means. Fatal bleeding is rare.

Öhngren has published his results of operation for malignant tumours of the maxillo-ethmoidal region. In 187 cases treated by diathermy and radium during 1922 to 1931 there were fatal results due to hæmorrhage in 6, to pneumonia and cerebral complications in 7 each, marasmus in 4, heart failure in 3, erysipelas, embolism and anæmia in 1 each. The commonest cause of the bleeding was the cavernous sinus, and this usually occurred when the external carotid had not been ligatured.

*Œdema.* Slight swelling of the floor of the mouth or of the neck is fairly common after mouth and throat operations if very prolonged, if too weak a current is employed or if the current is allowed to pass for periods of more than ten to fifteen seconds.

After operations on the sinuses, the skin of the face or eyelids may be swollen or the œdema may affect the orbit or the meninges—20 cases of the latter in Öhngren's series. As a rule the swelling disappears in a few days and causes no serious complications.

Septic infections of the lower air passages rarely occur if intratracheal anæsthesia is employed and the pharynx is properly plugged so that blood and pus are prevented from passing down into the lungs.

*Skin.* The healing of skin incisions made with a cutting current is always a little uncertain, and with some instruments it is definitely poor. When making cuts which will be noticeable afterwards I therefore prefer to incise the skin with a scalpel unless there is any fear that it is involved in the growth. Occasionally, after dividing the skin by electrosection, cheloids may develop later, but for some unexplained reason this never occurs in mucous membranes, which are nearly always smooth, flexible and free from scar tissue if not diseased.

## Special Operations

*Nose. Sinuses.* Malignant growths : Surgery alone has given unsatisfactory results. The combination of surgery, diathermy and irradiation marks a great advance in the treatment of these cases. The method that we have adopted during the last fifteen years is as follows : Every suspected case is given a preliminary treatment with X-rays, one-third dose : a biopsy is then performed : if malignant, the growth is exposed usually through the palate, which is removed after its soft coverings have been incised with a cutting current. The visible growth is coagulated with diathermy and removed with a loop or cutting knife : the outer nasal wall, turbinates, ethmoidal cells and sphenoids are all cleared of disease in this manner. If necessary, even the orbit can be exenterated through this opening. When disease is situated high up in the ethmoids and involves the skin or orbit it may be necessary to expose it with an incision through the skin, but this should be avoided if possible. After the sloughs have separated the cavity is treated with radium. Usually a slow treatment is given with 15 to 20 mg. on a stent which is placed in the cavity for one to two hours twice daily for about a month. Some surgeons prefer to use large doses of radium, such as 50 to 100 mg. inserted in the cavity immediately after the operation and retained for one or two days.

For the neck, when no glands can be felt, it has been our practice not to give any ray treatments. If small glands, which are movable and unilateral, can be felt these are removed by block dissections followed by irradiation. When inoperable, irradiation only is employed using either X-rays or radium bomb or collar.

Complications in the orbit may occur after diathermy and irradiation, and often it is impossible to lay the blame on one more than the other. In the early stages there may be severe swelling of the orbital tissues or of the conjunctiva on the affected side. This may be followed later by infection or suppuration. Temporary conjunctivitis is very common and may be severe. A cataract may develop due to irradiation months after treatment. In cases that have required very radical diathermy and severe irradiation the sight of the eye may be destroyed.

During the past fifteen years we have treated by this method 70 cases of carcinomata, of whom 20 are living for one to eight years; 29 cases with sarcomata, of whom 15 are living for long periods; 11 endotheliomata, 3 of whom are living free from disease.

Öhngren has treated 187 cases: carcinomata, 135; sarcomata, 39; mixed tumours, 13. With diathermy he removes the growths in a very radical manner and in many instances also gives treatment with irradiation both locally and for the neck. He lays great stress on the importance of the situation of the growth and its degree of malignancy. According to these conditions he has had five-year cures in 33 to 78 per cent., which are the best published results that I know of.

New published 97 cases of antral growths treated with diathermy and radium, with no operative deaths, and with over 30 per cent. cures.

Quick has had similar results, using surgery and radon seeds in 225 cases.

*Tongue, Floor of Mouth, Lips, Buccal Mucosa and Palate.* Diathermy is still favoured by many surgeons for the treatment of growths in these situations and gives better results than surgery alone. On the other hand, such good results have been obtained by radium needles that, personally, I only employ diathermy or the cutting knife after irradiation for the removal of indurated scars which may contain residual cancer cells, for the destruction of fibrous sloughs which are septic and adherent, and in the treatment of chronic ray sores. Stanford Cade has used diathermy and endothermy extensively on these lines and has published a very good account of the indications for these methods, also a bibliography of representative papers by other authors. I have also described the different methods of using high-frequency currents in these regions in the *British Journal of Surgery.*

*Tonsil and Pharynx.* The treatment of chronic tonsillitis by diathermy is described by the late Dan McKenzie on p. 507. This treatment has been employed in this country ever since Nagelschmidt gave his demonstration in 1910 and more recently all over the world. It is certainly of value in selected cases but there are many drawbacks. Many incorrect statements have been published, and those who are interested in this subject would do well to read a short paper by Dr. Graham Brown and Dr. Duhig, of Brisbane.

Surgery still remains the best treatment for infected tonsils.

*Malignant Growths of Tonsil.* At the present day nearly every surgeon is agreed that these growths are so malignant that simple removal with the knife is dangerous and ought never to be attempted. Diathermic and cutting currents have been extensively employed. Personally, I have treated many cases with them, but in recent years only those in which irradiation has failed.

To remove a growth of the tonsil may be comparatively simple, and in early cases the whole disease can be dissected away with a blade electrode, the base of the fossa being afterwards treated by desiccation. But when the disease has infiltrated the muscles it may be quite inoperable. In such cases one must decide whether to treat the disease with rays, *e.g.*, radium needling, bomb, X-rays, etc., or by coagulation. With the latter there are definite risks of hæmorrhage, which can be obviated to some extent by preliminary ligature of the external carotid artery, and of sepsis involving the neck. Moreover, it may not be possible to remove all the primary growth. In view of the good results that have been obtained by Berven, Cade and others with irradiation, it seems probable that this will prove a better method of treatment than diathermy for the majority of pharyngeal growths, particularly if the disease is in an advanced state.

Treatment of the neck is also imperative in all cases and follows the same lines as those laid down for growths in the nose and sinuses. One of the best accounts of the use of diathermy in these regions and the results that can be obtained by it will be found in some papers by Norman Patterson, who has reported on 109 cases and who has included the recent bibliography of this subject.

*Larynx.* Reference is made later (p. 502) to the uses of desiccation for simple growths. The cutting current is also employed by some surgeons to remove malignant growths of the epiglottis after laryngo-fissures or at certain stages of a laryngectomy. Also it is of value in stopping oozing from the small vessels and for sealing others that have been picked up with forceps.

*Œsophagus and Post-cricoid Region.* The treatment of malignant disease in these regions is still very unsatisfactory, and, as a rule, palliation of symptoms is all that can be hoped for. Surgical methods, including treatment with bougies, intubation, gastrostomy and resection of the disease are still widely practised but have very grave drawbacks. In the same way the results of diathermy have not proved reliable and, personally, I have largely abandoned the method. If the patient is well enough the best treatment is irradiation either with deep X-rays, as carried out by Finzi and Levitt, or with radium intubations or seeds with or without gastrostomy.

Although the mortality of this disease is still 100 per cent., ray treatment may be a valuable palliative measure and the patient may be temporarily relieved of all serious symptoms for a considerable period.

The use of diathermy for growths involving the post-cricoid region or œsophagus is described in the Appendix on p. 488.

*The Ear.* Rodent ulcers occur fairly commonly on the pinna and can be treated successfully by excision with the cutting current or by diathermy. On the other hand, still better results can be obtained by radium plaques or needling, the ray treatments causing little or no deformity.

Carcinomata are also occasionally seen both on the outer ear in the meatus and in the middle ear. For early lesions, radium or localised diathermy may be sufficient. When the disease is extensive and has involved the bones of the middle ear or mastoid it is advisable to remove the disease very radically with diathermy, if necessary taking away the whole of the external ear and the mastoid cells, afterwards treating the cavity with a radium plaque to destroy the inaccessible cells. To be successful this treatment must be very radical indeed, but if the disease is treated in this way it can often be arrested for long periods. For some unexplained reason the glands in the neck do not become involved until there is very extensive disease, and even when it has invaded the meninges it may be possible to arrest it for a long time with diathermy and radium. The worst cases are those in which the parotid gland is involved.

### REFERENCES

BERVEN, Prof. E. G. E. "Malignant Tumours of the Tonsil," *Acta Radiol.*, 1931.

GRAHAM BROWN, R., and DUHIG, J. V. "Electro-coagulation of Tonsils." *Med. Journ. of Australia*, 1932.

HARMER, DOUGLAS. "Diathermy of Tongue." *Brit. Journ. of Surg.*, 1928.

HARMER, DOUGLAS. "Radiotherapy for Cancer." John Murray, 1932.

HARMER, DOUGLAS. "Malignant Disease of Upper Jaw." *Lancet*, 1935.

NEW, GORDON B. *Archiv. Oto-Laryngol.*, 1931.

ÖHNGREN, L. GEORGE. "Malignant Tumours of Maxillo-Ethomoidal Region." *Acta Oto-Laryngol.*, 1933.

PATTERSON, N. "The Use of the Diathermy Knife in Malignant Disease of the Mouth, Nose and Pharynx." *Lancet*, 1934.

QUICK, D. "Sinuses and Nose." *Radiol.*, 1930.

SPENCER and CADE. "Diseases of the Tongue." Lewis, 1931.

## APPENDIX

*(By Author of the Present Book.)*

Since the publication of the second edition of the present volume the use of diathermy for the treatment of malignant disease of the upper air passages and the œsophagus has largely been replaced by the application of radium or X-rays. Considerable experience was gained by some workers, however, in the diathermic treatment of malignant growths of the parts mentioned, and their results were not altogether unsatisfactory. For this reason a brief account of the technique that was adopted and the results that were obtained may not be out of place.

### Post-cricoid Region of Pharynx

For growths obstructing the post-cricoid region of the pharynx a special electrode shown in section in Fig. 149 was used. It consisted of a short ebonite rod terminating in a conical head. The rod bore, on part of its surface, a metal cheek of the same length as the rod. In breadth, the cheek measured one-quarter of the circumference of the rod. The electrode was attached to the holder EC shown in Fig. 150. The holder was secured to the handle AB which was grasped by the operator.

After the coagulation of the growth a tube was passed through the stricture and maintained in position for three days in order to allow the passage of food during the period of œdema and swelling.

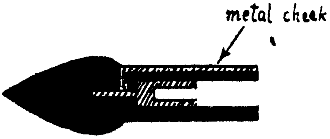

Fig. 149.—Active Electrode used in treatment of Post-cricoid Growths.

Using the above-described electrode, Harmer treated a number of cases of post-cricoid carcinoma. Afterwards he abandoned the method in favour of radium. In two of the original cases the obstruction to swallowing was relieved for a few months and the general condition of the patient improved considerably. The third case derived no relief, and the fourth was slightly benefited. Two other cases died on the fifth and eighth days, respectively, after the operation, one from hæmorrhage and the other from bronchopneumonia.

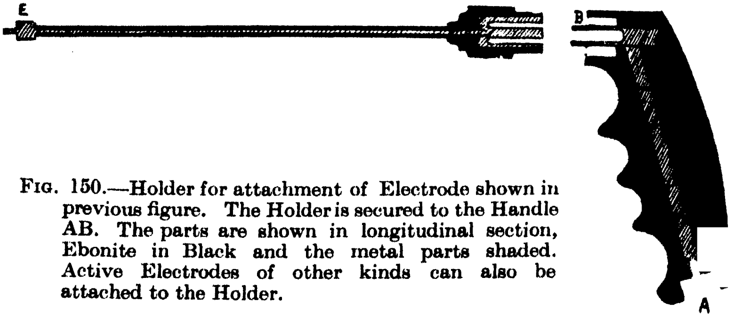

Fig. 150.—Holder for attachment of Electrode shown in previous figure. The Holder is secured to the Handle AB. The parts are shown in longitudinal section, Ebonite in Black and the metal parts shaded. Active Electrodes of other kinds can also be attached to the Holder.

The late Dan McKenzie treated several cases of post-cricoid carcinoma by diathermic coagulation. He used a blunt electrode attached to a long handle. The effect on swallowing was good. He found it difficult to estimate the depth of coagulation. In two of his cases abscesses formed at the root of the neck and long tortuous fistulæ were left.

Diathermy gave some good results in cases of carcinoma of the epiglottis. But in the treatment of growths in the region of the upper laryngeal orifice elsewhere it was unsatisfactory.

### Naso-pharynx

A case of angio-sarcoma of the naso-pharynx was treated by Broughton Barnes by surgical diathermy. He removed the growth by means of his snare electrode (Fig. 155, p. 499). There was no loss of blood and the patient was free from recurrence two years later.

The patient was a boy of 13. The tumour arose from the basi-sphenoid. It was 1 in. long, and its pedicle was ½ in. broad and ¼ in. thick. The body of the tumour was 1 in. in breadth and ¾ in. in thickness. Its free end was visible below the soft palate. The boy had had two severe attacks of hæmorrhage before he was brought for treatment. Under general chloroform anæsthesia the snare was passed through the mouth over the tumour and forced against the basi-sphenoid by the finger. The snare was tightened and the current started. The tumour fell free in about five seconds. There was no stain of blood. The patient had absolutely no discomfort after the operation. Two years later there was no sign of recurrence, nor had there been any hæmorrhage since the operation. The histological appearance of the growth was that of an angio-fibro-sarcoma with enormous numbers of large thin-walled vessels extending even into the epithelium.

Mr. Broughton Barnes, who kindly furnished the writer with the particulars of the case, stated that the only precaution necessary was to maintain the pharynx in a low position when the tumour fell.

### Œsophagus

Special electrodes were devised by C. G. Teall, of Birmingham, and by A. J. Wright, of Bristol, for the coagulation of growths of the œsophagus. Teall's electrodes are illustrated in Fig. 151, A, B, C. They were made of ebonite. A and B contained small rectangular metal cheeks, their long axes being transverse in A and longitudinal in B. These electrodes are attached to insulated metal stems of suitable length. The other ends of the stems are secured to handles for the operator.

The stricture was brought into view by means of an œsophagoscope and the free end of the electrode was engaged in the proximal end. When the metal cheek made contact with the growth, the current was started and the electrode moved slowly downwards. The growth was coagulated along a path from above downwards. The electrode then was slightly rotated and slowly withdrawn. In this way a second path was coagulated by the side of the first. If necessary, the electrode was again rotated and again passed downwards.

The electrode shown in Fig. 151, C, is also made of ebonite. At its proximal end is a metal dome. When this electrode was used it was passed through the stricture before the current was started. The metal dome was then brought into apposition with the distal end of the stricture and the current started. Then it was slowly withdrawn through the stricture which, in consequence, was coagulated along its entire length.

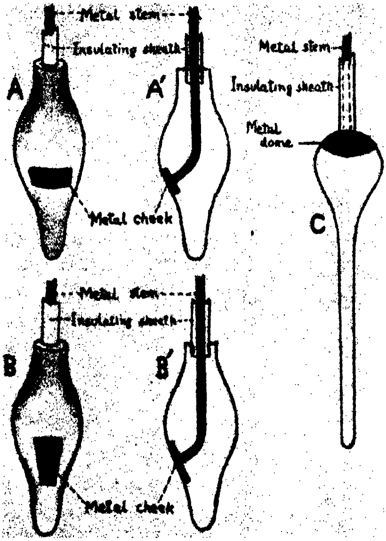

FIG. 151.—Teall's Electrodes for treatment of Malignant Strictures of Œsophagus. A and B are shown in section at A′ and B′.

An œsophageal tube was placed in position after the operation in order to prevent complete obstruction of the lumen which the swelling and œdema might otherwise have caused. It was removed after three days.

The electrode (Fig. 151, C) is a modification of a similar one that was devised by Wright. In place of the dome Wright's electrode was fitted with a metal ring with a cutting edge. It was passed through the stricture to the distal end; the current was started and the electrode slowly withdrawn. The cutting edge came into contact with the growth, coagulating and cutting it at the same time.

There would seem to be more risk of bleeding if Wright's electrode were used. With Teall's electrode there was coagulation without cutting.

The treatment of post-cricoid and œsophageal growths by surgical diathermy is difficult because the process of coagulation is hidden from the eye, and the depth to which the current coagulates the tissue must remain a matter of judgment. Some idea of the depth to which coagulation occurs with currents of different strength and with different rates of movement can approximately be obtained by making preliminary experiments on raw meat.

Considerable experience in the treatment of œsophageal carcinoma was obtained by Musgrave Woodman. In a discussion on the treatment of malignant disease of the upper air and food passages he stated that he had had sixty cases with œsophageal disease. He had not been able to cure any of them, nor was he sure that he had been able to prolong life to any appreciable extent. In nearly all instances, however, he had enabled the patients to eat ordinary food *per vias naturales* until death occurred from extension of the disease. The results were superior to those obtained by gastrostomy. The patients were able throughout the disease to swallow freely by the ordinary route. The operation was well borne and produced very little shock.

## CHAPTER XLII

# TREATMENT OF NON-MALIGNANT GROWTHS AND OTHER ABNORMALITIES OF THE UPPER AIR PASSAGES

IN the treatment of certain kinds of non-malignant growth the electrothermic methods yield results better than those obtained by the knife. The power of the diathermic current to coagulate tissue *en masse* without disturbing its anatomical continuity or that of its vessels may be utilised with advantage in the treatment of highly vascular neoplasms such as fibromata of the nasopharynx and angiomata. Neoplasms of this kind can be destroyed without loss of blood.

Ulcers and granulomata caused by infection are especially suitable for treatment by diathermic coagulation, not merely for the reasons stated above, but for the fact that the infecting organisms are destroyed within the coagulated tissue. The permanence of the result of treatment of papillomata of the urinary bladder by diathermic coagulation may perhaps be due to the sterilisation of the growths as they are destroyed.

It has already been mentioned that the scar tissue which replaces morbid tissue after coagulation of the latter by diathermy does not shrink or form adhesions with parts in contact. For this reason diathermy is of value in removing or dividing bands of scar tissue, such as synechiæ, and in freeing adherent organs such as the tongue when bound to the floor of the mouth after scalpel operations.

Diathermic coagulation can be successfully employed for the purpose of sealing bleeding points on the lip, nasal septum, etc. In this way hæmorrhage has been permanently stopped.

## Angiomata

Coagulation by diathermy is a particularly efficient form of treatment for angiomata of the tongue, lips, pharynx and buccal mucous membrane. They can be destroyed usually at one sitting, even if they are of large size. After healing it is sometimes difficult to realise that any operation has been performed.

The following case (E. G.) is a good example of the power of diathermy. Surgical treatment was considered inadvisable and electrolysis had failed. It is of interest as it was the first in this country to which diathermy was applied for surgical purposes. It was one of the three treated by Nagelschmidt at St. Bartholomew's Hospital on October 21st, 1910.

E. G., aged 17. A large pulsating nævus was present on the right side of the tongue and floor of the mouth. A general anæsthetic was given and the nævus coagulated by diathermy. There was no loss of blood. A large slough formed. It separated ten days later and healing was complete four weeks after the operation.

Four years later (October, 1914) the patient came to hospital again, saying that she had noticed some patches of nævus in her mouth. On examination it was seen that there was a small mass of nævus, the size of a small bean, on the right side of the tongue, and two small patches of nævus, one on the tonsil, the other on the wall of the pharynx. Except for the patch of nævus the tongue and floor of mouth in the situation of the original nævus were quite normal in appearance.

On October 7th, 1914, the nævus on the side of the tongue was transfixed with the single needle electrode and coagulated under local anæsthesia. The slough separated, and by October 26th the part had completely healed, leaving no trace of nævus. The other patches were treated similarly, with equally good results.

A number of cases of nævus of the tongue and lips have been treated by the writer by diathermic coagulation. Multiple needle electrodes, like those illustrated in Fig. 108, Nos. 12 and 13, were used and the current was increased until the tissue whitened from coagulation. There was no bleeding during the operations or afterwards. Soft pliable scars were left on the lips. In the tongue cases a close inspection was necessary in order to detect any difference between the part originally subjected to diathermy and the adjacent regions.

A photograph of one of the cases is reproduced in Figs. 152 and 153.

The following case illustrates the potency of diathermy in preventing recurrent bleeding after other methods have failed.

E. L., aged 17. (Mr. Harmer's case.) This patient had an extensive nævus in the right wall of the nose, in the skin and mucous membrane. She had suffered from severe hæmorrhage from the nose on different occasions, and had been under treatment at intervals since the age of 5. The facial artery and the external carotid artery had, on different occasions, been ligatured, but without avail. During some of the attacks the hæmorrhage was furious, leaving the patient nearly completely blanched. One of these attacks occurred in hospital and was actually seen. The last attack occurred in May, 1914, and the blood escaped from a channel in the septum in the region of the septal artery. The hæmorrhage was temporarily stopped by pressure. The part was then coagulated by diathermy (in May, 1914). During the following years the patient had no further attacks of hæmorrhage.

FIG. 152.—Angioma of Lip. Before treatment.

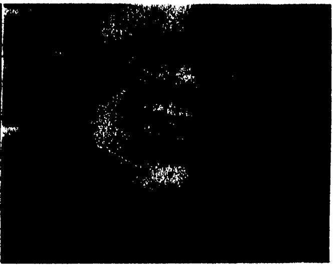

FIG. 153.—After treatment of Angioma of Lip by Diathermic Coagulation.

## Bleeding Points in Nose and Lips

Bleeding points can be immediately sealed by means of diathermy. In the case of the lip a single needle electrode is inserted for about one-eighth of an inch through the mucous membrane at the point from which the blood is escaping. The current is gradually increased from zero until coagulation is first noted. It is then switched off. It must not be allowed to pass for a longer time because the tissue in contact with the needle will dry and become adherent to the metal. If this happens the withdrawal of the needle will bring away adherent tissue and bleeding will at once start afresh.

In the case of the nasal septum a ball electrode of the smallest size should be used. The current should be stopped at the moment when coagulation is first noticed. If it is allowed to pass for a longer time coagulation will proceed to a greater depth and the septum may be perforated. The same event may occur if a needle electrode is used.

The heating of tissue accelerates and increases the circulation through it, and if the coagulation caused by the diathermy is insufficient, the bleeding will start afresh after removing the electrode. If this occurs the bleeding may be stopped temporarily by desiccation, as advised by Dan McKenzie. By lifting the active electrode a short distance from the bleeding point the sparks will pass on to the latter. An adherent cake of charred blood will form. This is " sufficient to cover the bleeding vessel with an adherent cake of charred blood, after which the more deliberate coagulation of the area may be proceeded with " (Dan McKenzie).

Three cases of persistent bleeding from the lower lip were treated by the writer by diathermy. The hæmorrhage stopped at once. There was no recurrence during the periods for which the patients were kept under observation, and it may be concluded that the results were permanent. One of these cases was in an old lady who had been rendered considerably anæmic by loss of blood. She came with her doctor during an interval of freedom from hæmorrhage. A zinc needle was inserted into the lip and a galvanic current was passed, the object being to seal the opening by means of zinc ions and the formation of insoluble albuminate of zinc. After withdrawal of the needle, however, there was a copious outpouring of blood. It was controlled by pressing the lip between the fingers while the preparations were made for diathermy. A single needle electrode was inserted and the tissue around it coagulated. The pressure was cautiously relaxed and four eyes gazed anxiously at the lip. Bleeding did not occur and the subsequent history showed that the opening had been permanently sealed.

### Lupus and Tuberculous Ulcers

In the treatment of lupus of the mucous membranes in regions where the local application of ultra-violet light is impossible, the late Dr. Dan McKenzie thought that diathermy might be applied with advantage, and he regarded it as superior to curettage and chemical caustics. He had noted, in many cases, the appearance of new nodules in the apparently healthy tissue adjacent to that in which the lupus was destroyed. This phenomenon is noticed also after the treatment of lupus nodules in the skin. Considerable patience is necessary, therefore, and the local treatment by diathermy should be supplemented by general application of ultra-violet rays to the skin.

The following case is one of tuberculous ulcer of the nasal septum. It healed after diathermic coagulation when treatment by other methods had failed. Although ulceration recommenced at later dates it was always healed by further applications of diathermy.

The patient, an adult male, had a tuberculous ulcer on the lowermost part of the nasal septum and the adjoining part of the upper lip. It measured ¾ in. by ¼ in. A small granuloma was present immediately above the ulcer. The base and edges of the ulcer and the granuloma were coagulated, after procuring local anæsthesia. A single needle electrode was used and the morbid parts, together with the healthy tissue at the edge, were coagulated piecemeal.

The coagulated parts sloughed away and the residual ulcer healed. Four months later a minute ulcer was noted by the patient on the septum in the uppermost part of the scar. This was coagulated by diathermy and healing took place. Nine months later a very small ulcer was seen in the same situation. Elsewhere the scar was healthy. The recurrent ulcer was again coagulated by diathermy. The portion of the scar on the lip remained healthy since the first coagulation, *i.e.*, for a period of thirteen months. The ulcer had received several applications of ionisation but could not be made to heal. The patient suffered from quiescent pulmonary tuberculosis.

In a communication to the writer, W. J. Harrison, of Newcastle-on-Tyne, described some good results which he had obtained in the treatment of lupus of the palate, pharynx and fauces by diathermic coagulation. In the case of the posterior pharyngeal wall he used a small disc electrode and moved it over the affected region while the current was passing. The lupus nodules appear to be destroyed by a less high degree of heat than the normal tissue.

### Fibromata in the Nasopharynx

The severe and sometimes fatal hæmorrhage which accompanies excision of these growths renders the use of the knife dangerous. A case was treated by diathermic coagulation at St. Bartholomew's Hospital by the late Mr. Rose, who kindly allowed the writer to report it. The active electrodes which were used were specially designed for the purpose. They are shown in Fig. 154. They consist of ebonite rods, 4 mm. in diameter and 10 cm. in length. They contain metal cores for conducting the current. One end of the metal is screwed into a handle (not shown in the figure). The other end terminates in a metal disc which bears a very short point. This point serves to anchor the free end of the electrode and prevent its movement off the surface of the growth. The straight electrode approaches the growth through the nasal cavity. The curved electrode reaches it from under the soft palate. These electrodes were devised because the single needle electrode which was used on the first occasion punctured the growth and caused profuse hæmorrhage.

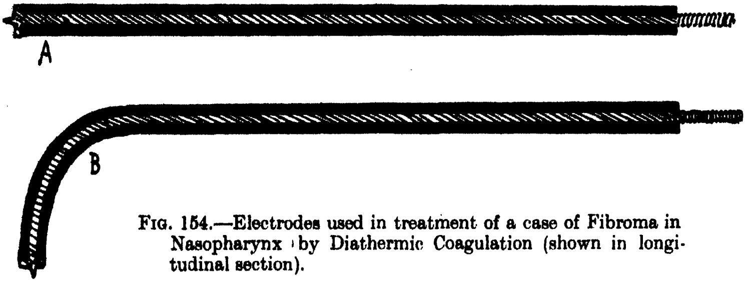

FIG. 154.—Electrodes used in treatment of a case of Fibroma in Nasopharynx by Diathermic Coagulation (shown in longitudinal section).

J. S., aged 14. A fibroma of the nasopharynx had been removed by the knife on a previous occasion, but it had recurred. Diathermy was then employed. The first attempt was a failure for the reason stated above. On the second occasion the electrode shown in Fig. 154 (A) was used. It was applied in succession to different parts of the surface, and the current was directed through various regions of the growth. The current attained a value of 1·2 amperes and was allowed to pass for thirty seconds at each application of the active electrode.

Two months later the diminution in size of the growth was evident. A second series of applications was made.

Four months after the second operation a third series was made, the growth being approached from under the soft palate. The remains of the growth sloughed away almost completely after the third operation, and when the patient was last seen (one year afterwards) there was a very small remnant visible and the symptoms of obstruction had disappeared.

The patient did not stay for more than two or three days in hospital after each operation, and there was no rise of temperature, except on one occasion, when it reached 100° F. There was no post-operative shock on any occasion.

## Teratoma

By means of his diathermic snare electrode (see Fig. 155) Broughton Barnes removed a teratoma from the nasopharynx in a boy aged five months. The writer is indebted to him for details of the case and for permission to publish them.

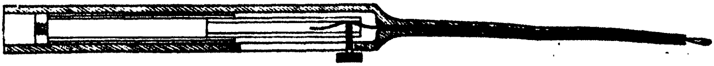

FIG. 155.—Diathermic Snare Electrode devised by Broughton Barnes (seen in longitudinal section).

The tumour was 1¾ in. long, and a little more than ½ in. broad at its maximum diameter. It arose apparently from the sphenoid. The upper inch consisted of a long pedicle about as thick as a slate pencil. The body of the tumour normally lay in the hypo-pharynx, but was occasionally hawked up into the mouth. It was pink in colour and covered by normal skin bearing copious fine whitish down.

Under general chloroform anæsthesia the tumour was pulled up into the mouth by a pair of Spencer-Wells forceps and the snare was threaded over it, passed into the nasopharynx and pressed against the sphenoid. The current was started and the pedicle severed. The tumour came away in about ten seconds. There was no hæmorrhage. Owing to the very small space available there was slight scorching of the soft palate, and the baby had slight œdema of this part for forty-eight hours. Five months later there was no sign of recurrence.

The snare electrode designed by Broughton Barnes for the removal of the post-nasal growths is shown in Fig. 155. It is made of vulcanite. The broader portion contains a metal liner. The cable from the diathermic machine is screwed into the lower end of the liner. The liner contains a hollow metal slide which can be made to move along the liner. The wire, which is made of hard-drawn silver, is passed through the stem and its ends are gripped in the slide by a vulcanite-headed screw. The head of the screw projects through a slot, thereby enabling the operator to draw the slide into the liner and pull the wire loop into the stem of the electrode.

The cable is screwed into the liner and connected to the diathermic machine. The circuit is completed by an indifferent electrode which is applied to some convenient part of the body and connected by a cable to the other terminal of the machine. The current passes along the liner, the slide and the wire to the loop which projects from the free end of the stem, and enters the tissue where it is grasped by the wire loop. It passes to the indifferent electrode. The tissue in contact with the wire loop is coagulated. As the wire is drawn into the stem the coagulated tissue is cut through. The operation is one of combined coagulation and cutting, and if the wire is drawn with sufficient slowness the tissue in advance of it will be coagulated before it is cut.

## Synechiæ

When adhesions between the septum and lateral wall of the nasal cavity are divided by the knife or hot metal they are liable to form again unless the parts are separated artificially until healing occurs. Dan McKenzie recommended the treatment of the synechiæ by diathermic coagulation. He said that the reaction is trifling and often absent, and that there is little or no tendency to the recurrence of the adhesion. There is no need, therefore, to maintain an objectionable foreign body in the nasal cavity during the process of healing.

## Adherent Soft Palate

Two cases of adherent soft palate, one in a boy of seven, the other in a man of twenty-five, were treated by Douglas Harmer by diathermy. By means of a blade electrode the adhesions were divided and the palate freed. The adhesions re-formed and no improvement was effected.

The failure was possibly due to the fact that the parts were allowed to remain in contact during the healing of the ulcers which were left after the separation of the sloughs. Further trial should be given to diathermy, and the precaution mentioned should be observed.

Dan McKenzie has employed diathermic coagulation as a means of reopening the nasopharynx and posterior nares after they have been more or less obliterated by scar tissue after luetic ulceration. The treatment proved to be no more successful than the older methods (*Acta Oto-Laryngologica*, Vol. VII., fasc. 4, p. 589).

### Leucoplakia

Electrodesiccation is effective in cases of leucoplakia. In comparison with zinc ionisation it is a much more rapid method. Douglas Harmer has had considerable experience of the method in the treatment of leucoplakia of the buccal, lingual, pharyngeal, palatal and nasal mucous membranes.[1]

A case of leucoplakia of the *tongue* was treated by the writer. There were several patches on the sides, tip and inferior aspect of the organ. A portion of the mucous membrane was anæsthetised by injecting novocaine and adrenalin and the patches of leukoplakia were desiccated. The patient, a gentleman of fifty-three, did not tolerate the treatment well. He complained of disagreeable spasmodic twitches of his tongue every time it was sparked. These twitches, occurring in a freely movable organ like the tongue, rendered it difficult to restrict the sparks to the spots desired. For this reason the remaining patches were treated by a combination of ionisation and freezing (with carbon dioxide snow). The electrodesiccation, however, was quite successful because there was no recrudescence of leucoplakia in the part treated by it. The patient was last seen two years after the desiccation.

### NOTE ON THE TREATMENT OF CERTAIN DISEASES OF THE UPPER AIR PASSAGES BY FULGURATION (ELECTRODESICCATION)[2]

Except in small localised diseases a general anæsthetic is advisable, and as the patient must be absolutely still an injection of avertin or evipan followed by gas and oxygen should be given.

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[1] A high-frequency current which passes in the form of sparks between an electrode and the body has some power to stimulate muscle and nerve, even though the frequency of the oscillation is high. It has this power because its average strength in one direction is greater than that in the reverse direction. In other words, the current is "partially rectified."

[2] The information given under this heading is quoted from a note by W. Douglas Harmer in *The Practitioner*, July, 1935, Vol. CXXXV. (Article on "Fulguration and Electrodesiccation" by Cumberbatch and Harmer.)

In the larynx special electrodes are used which are insulated in such a manner that the sparks can be focussed on any points without damage to the neighbouring tissues. The movement of the vocal cords is so free that unless all reflexes have been controlled by thorough anæsthesia and by instruments which protect the normal parts it is impossible to operate with safety. With proper care desiccation is probably the best treatment for all small innocent growths in the larynx. Tiny nodules, such as singers' nodules, can safely be destroyed by a fine wire which can be pushed in and out of an insulated tube by a trigger on the handle of the instrument. Growths such as papillomas can be similarly treated, or if too large the greater part can first be removed by the cutting arc,[1] using a small snare or wire loop, and then the base can be thoroughly treated with sparks. Rarer growths, such as an angioma, can be destroyed by desiccation with perfect safety.

Thus, a small vascular neoplasm on the anterior part of a vocal cord was destroyed without any bleeding or soreness. Perfect healing resulted and after a short period no visible scar could be seen. The voice, which had been husky, became quite normal again and the patient, who was a prominent man and used his voice a great deal, was delighted.

Undoubtedly the danger of recurrence is less when such a growth is destroyed by heat and not by cutting. Also desiccation is applicable and often the best treatment for many forms of surface inflammation, such as chronic tubercle, pachydermia and superficial leucoplakia. If sufficient care is taken to learn the technique, and provided with suitable instruments and a good anæsthetist it is undoubtedly a better treatment than removal by forceps because there is less trauma and no bleeding; also the wound heals with less inflammation, with little discomfort and with no scarring which is likely to cause deformity or serious damage to the voice.

In the mouth, desiccation is a very excellent treatment for patches of superficial leucoplakia, particularly those which have suspicious sores and are causing serious discomfort. In such cases it is unnecessary to destroy the deeper tissues and it is doubtful if the progress of the disease can be arrested by removing them. Even extensive lesions invading the greater part of the lining of the cheek, or the surface of the tongue, can be successfully treated by desiccation. Thus, it may be possible to keep the patient comfortable for many years and so prevent the occurrence of malignant disease.

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[1] The use of the cutting arc for the purpose of excising tissue (electrosection) is described in Chapter XXXIX.

The worst instance that I have seen of this type was a man who had suffered from extensive leucoplakia for years. At the age of 63 suspicious sores appeared, which were easily cured by desiccation, but the treatment had to be repeated several times. Twelve years later a gland had to be removed from the submental region and was found to be infected both by tubercle and carcinoma. Sixteen years after the desiccation he succumbed to the metatases.

In the same way the treatment may be successful for patches of lupus on the palate, on the pharynx or in the nose, for tuberculous sores on the tongue, for papillomas or small growths in the mouth or in the nose. Finally, it is constantly employed to singe the base of attachment of malignant growths after they have been removed by electrosection, particularly local diseases such as rodent ulcers or tumours such as the carcinomas of the tonsil when one wants to cauterise the tonsillar fossa thoroughly without burning the pharyngeal wall too deeply. In many of the above conditions desiccation is, indeed, most valuable because of its simplicity, safety and good results.

## REMOVAL OF ENLARGED TONSILS BY ELECTROTHERMIC METHODS

### (*Preliminary Note*)

After the introduction of the surgical diathermic method of treating tonsils, the possibility of removing them without the necessity of general anæsthesia, and without confinement in a nursing home, caused an increasing demand on the part of the public for the new method. For a few years diathermy was widely, not to say indiscriminately, employed. It is now generally realised that electrothermic methods cannot replace the use of the scalpel as a routine procedure.

Electrocoagulation or electrodesiccation cannot be adequately practised in one application. Further, unless they are practised by one who is accustomed to throat surgery and at the same time familiar with the use of electrothermic methods, there will always be the likelihood of incomplete removal of the glands, and portions are likely to be left behind.

Nevertheless, there is a place for diathermy in the treatment of unhealthy tonsils. Their removal by electrocoagulation can safely and efficiently be practised in cases where their extirpation by the customary method would, for various reasons, be an unsafe procedure. The following chapter was written by the late Dr. Dan McKenzie. As a laryngological surgeon, and one who had obtained wide experience in treatment by diathermic coagulation, he has described his method and expressed the views he held as to the place which diathermy should occupy in tonsillar surgery.

The following is a brief account of the development of the use of surgical diathermy in the treatment of abnormal tonsils.

The coagulation of tonsils by diathermy was first demonstrated in this country by Nagelschmidt, at St. Bartholomew's Hospital, in October, 1910. In August, 1913, the writer coagulated the tonsils of a girl, aged 17, by means of a multiple needle electrode. The neck became much swollen soon after the diathermy, but the patient did not suffer much discomfort, and the swelling subsided completely. After separation of the slough it was found that the tonsils had not been completely destroyed, although it appeared at the operation that coagulation of the entire mass had occurred. A general anæsthetic was employed during the operation.

In 1913, H. D. Gillies (now Sir Harold Gillies) operated on the tonsils of three children aged, respectively, 7, 4 and 14. In the first case the tonsils were transfixed at the bases by a single needle electrode. In the other two the blade electrode was used and the combined coagulating and cutting operation performed. There was no bleeding during the operations. The patients did not complain of pain or difficulty in swallowing. In one case there was slight bleeding the day after the operation.

In a discussion on Surgical Diathermy (v. *Proc. Roy. Soc. Med.*, Vol. XI., No. 9, Section of Electrotherapeutics), Dan McKenzie stated that he had destroyed enlarged tonsils by diathermy in adults, leaving intact faucial pillars and a smooth scar. There was no hæmorrhage.

Writing in the *Acta Oto-Laryngologica* (Vol. VII., fasc. 4) the surgeon above mentioned stated that he had, on more than one occasion, used simple dissection for one tonsil and diathermic dissection for the other, and had found that, after healing, it was impossible to distinguish any difference between the two cicatrices.

The combined coagulating and cutting operation seems to have been the only method of employing diathermy which was originally practised by laryngological surgeons in this country for the removal of tonsils. There are, however, two other methods available. In the *first* of these the tonsil is coagulated in different parts by means of a single needle electrode. In the *second*, electrodesiccation is practised. These operations seem to have been first employed in the United States. They were performed under *local* anæsthesia in adults.

The author was present at a lecture-demonstration by Dr. Raymond Elmer at Chicago, in November, 1925, on the treatment of enlarged tonsils, by the *first* of these methods. Below is given a brief *résumé* of the lecture.

Dr. Elmer said that he used, for procuring local anæsthesia, ½ per cent. of novocaine to which are added 5 gr. of sodium chloride and 5 gr. of magnesium sulphate to the ounce. One drachm is injected *behind* the tonsil at about the centre of the posterior pillar. If the tonsil is submerged double the quantity of ¼ per cent. solution is injected so as to bring it more into view. Gagging can be prevented by swabbing the throat with 4·4 per cent. solution of cocaine. By means of a wooden spatula the tongue is depressed. The active electrode, which is of the single needle type, is inserted into the centre of the tonsil. By means of a foot switch the current is started and allowed to flow until the surface is seen to blanch from coagulation around the needle. The machine should be adjusted so as to give not more than 500 milliamperes. In most cases 350 milliamperes are sufficient. About seven separate punctures are necessary in order to coagulate the entire tonsil. There usually remains uncoagulated a portion of tonsillar tissue which lies buried under the anterior pillar of the fauces. By inserting the needle behind this pillar into the tonsil the latter can be readily brought into view and coagulated.

After the operation the patient is told to go home and remain indoors for two days. He can consume ordinary meals. He feels little discomfort. The addition of the magnesium sulphate to the anæsthetic has the effect of prolonging analgesia for a number of hours, thus giving the acute reaction time to subside.

On the third day after the operation the slough begins to soften and separate. Under no circumstances should it be removed artificially, as bleeding will occur. The slough is completely separated on the tenth to the twelfth day, and healing is complete on the fourteenth or fifteenth. During the sloughing the patient may resume his occupation and he feels very little discomfort.

Dr. Elmer stated that he had treated over 500 cases during two and a half years, the youngest patient being 15 and the oldest 85. In this series 15 suffered from secondary hæmorrhage, due, the lecturer thought, to premature separation of the slough. In most of these the bleeding was stopped by ordinary hæmostatic solutions. In 2 it was necessary to apply diathermy. Some severe œdema followed the treatment of the first 20 cases. This was due, the lecturer said, to the use of currents stronger than 500 milliamperes, and to the injection of the anæsthetic into the tonsil instead of behind it. There was no fatality, no pulmonary abscess, no pneumonia, no otitis media and no severe hæmorrhage.

Dr. Elmer entitled the treatment "electrocoagulation."

The *second* method of treating enlarged tonsils is that of desiccation. Surface anæsthesia is procured and the sparks are directed on the entire surface of the tonsil. Special directors are used which prevent the sparks passing elsewhere than desired. The superficial layers of the tonsil are desiccated at each application. The entire tonsil cannot be destroyed at one sitting. The operation is repeated every two or three weeks until the whole of the tonsillar tissue has been removed. This method was practised by William McFee, of Boston, U.S.A. It has not come into general use.

At the present time electrocoagulation is the procedure most commonly practised. A single needle is used as the active electrode and a number of séances are held.

## CHAPTER XLIII

# DESTRUCTION OF THE TONSILS BY DIATHERMY

BY

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Destruction of the faucial tonsils by diathermic coagulation has now been under review for several years, and it is gradually attaining to a definite position in the treatment of tonsil sepsis. Unfortunately, as so frequently happens with a new method, somewhat too enthusiastic claims have been made for it in certain quarters with the usual consequence: reputable authorities have been tardy in adopting it. But there is no doubt that it has come to stay, since in this agent we possess a means of eliminating tonsil sepsis in patients who otherwise would be left without any reliable remedy whatever against their disease.

(*Photo: Elliot and Fry.*)
The late Dan McKenzie, M.D. (Glasgow), F.R.C.S. (Edinburgh). (*The Lancet.*)

It is most suited for cases in which the ordinary surgical removal would be a risky proceeding, as in the old; or when general debility is pronounced; or in the presence of some such disease as exophthalmic goitre.

In addition to this class of patient, however, in which the ordinary operation is manifestly a considerable risk, one is frequently asked to use diathermy in people who decline to submit to the ordinary operation although they appear to be quite able to undergo it. Such patients are frequently of a highly nervous constitution and are likely to prove a trial to the medical man whatever method he adopts. In these circumstances the relative advantages and drawbacks of both methods may be placed frankly before the patient and the decision left with him. The following are points for his consideration.

With the ordinary operation, performed by a capable surgeon under a skilfully administered anæsthetic, the risk to life is, one may say, trifling, and post-operative pain and discomfort, though considerable to begin with, are over for good and all within a few days. Moreover, the operation is radical, the whole process being completed at one single intervention. It approaches, however, to the status of a major surgical operation, and necessitates a week or a fortnight in a nursing home or hospital.

With diathermic destruction, on the other hand, while there is, to all intents and purposes, no risk whatever to life, a certain amount of discomfort and sometimes even pain may follow each application of the agent. (This, however, is by no means invariable.) Again, the satisfactory elimination of the tonsil necessitates a succession of séances, and, as we shall see later on, total eradication of every morsel of tonsil tissue is often difficult to be sure of. One great advantage diathermy possesses; the patient can, as a rule, attend to his business throughout the whole course of the treatment. Hospitalisation is unnecessary.

Thus, while there are some patients for whom only diathermy can be safely employed, there are others for whom the ordinary operation is preferable, and there is a third group in which decision can only be arrived at after weighing the pros and cons of each method. We may add, by the way, that diathermy is not suited for the removal of tonsils in children.

The general indications for tonsil diathermy are, of course, the same as those for tonsillectomy, namely, first, recurrent tonsillitis with or without quinsy formation; and secondly, the suspicion of the tonsils acting as a focus of systemic infections, as in the various forms of rheumatism, and occasionally in such disorders as exophthalmic goitre and acute nephritis. Physicians sometimes also send us cases in which they blame the tonsils for gastric or duodenal ulcer or for appendicitis.

In the first of these groups, in which there is unmistakable local disturbance, the removal of the tonsils, whether by diathermy or otherwise, may be confidently expected to cure the patient. In the other groups, however, where the tonsils can only be regarded with suspicion, cure cannot be guaranteed, and it is well for the operator not to indulge in rash promises. These precautions apply, naturally enough, to the removal of tonsils whatever method be adopted.

SALAR JUNG BAHADUR

### Application of Diathermy

It is sometimes possible in highly insensitive patients to dispense altogether with any anæsthetic, local or general. But such fortunate people are rare.

On the other hand I have on occasion, dealing with excessively nervous people, used nitrous oxide anæsthesia for the first application. (Ether must not be used with diathermy.)

Again, one sometimes hears of experts whose patients are said to be perfectly contented with a single swabbing of the tonsils with a weak solution of cocaine. I have tried this simple plan, I may say, but without evoking very much enthusiasm. Indeed, unless I succeed in producing complete anæsthesia of the tonsil area, the patients who constitute my clientele are apt to make some sort of excuse, and put a stop to the treatment. For satisfactory results, in a word, the application must be painless.

The following is the routine I am employing at present. First of all the tonsils and faucial pillars are painted over two or three times with pure sol. adrenalin (1/1000). This causes a local ischæmia, in virtue of which the absorption of the local anæsthetic into the general circulation is minimised while its local action is intensified.

Then the same regions are repeatedly swabbed with sol. stovaine (10 per cent. in water). During this stage free salivation takes place, for which provision should be made.

The patient is instructed to keep the mouth open and not to make swallowing movements.

Next follow one or two surface applications only of 10 per cent. sol. cocain. hydrochlor. in an equal quantity of sol. adrenalin (1/1000).

Finally, several cubic centimetres of novutox (2 per cent.) —an antiseptic mixture of novocaine and adrenalin—are injected through a fine needle so as to infiltrate (*a*) the pillars of the fauces, and (*b*) the pharyngeal wall and soft palate deep to the tonsil. In this last step the needle must be kept outside of the tonsil so as to surround it with a zone of anæsthetic solution.

An important detail in the anæsthetising consists in waiting for ten minutes before beginning the little operation so as to give time for satisfactory anæsthesia to be produced.

The sparing use of cocaine is to be noted. Experience has shown that toxic phenomena are easily induced by cocaine solution applied to the pharynx. And, by the way, cocaine should never be used save in combination with adrenalin.

As regards diathermy electrodes for the tonsil, there is great variety. But I find as time goes on that I am relying almost exclusively upon a short needle. With an electrode of this shape one can regulate the extent and depth of coagulation more easily and precisely than with any other. When the needle is inserted into the tissues coagulation takes place relatively widely around the shaft while it is carried little or not at all beyond the point. Thus by using a needle we can limit the depth of coagulation, an important matter when we are nearing the tonsil capsule where the vessels enter and leave the gland.

In making our applications the current should not be turned on until the electrode is *in situ*, and it should be turned off before the electrode is removed. Otherwise sparking may occur to the alarm and consternation of the patient.

In using the needle it is often advantageous to make its buried portion, and with it the tonsil tissue, project towards the middle line. This not only facilitates inspection but it also shortens the time of coagulation by rendering the tissue bloodless.

The first application should be made in and around the supratonsillar fossa. This is a cul-de-sac running, as a rule, downwards and outwards through the body of the tonsil as far as the capsule. Into it open a number of crypts, and as its disposition hinders free evacuation and drainage it furnishes the most common site for septic invasion and should therefore be the first area to be coagulated and destroyed. The needle, or a suitably curved hook if preferred, having been inserted into the sac as far as the capsule, the current is switched on and coagulation allowed to proceed until the surface of the tonsil superficial to the fossa is seen to become bleached and white. This having been accomplished, the upper pole of the tonsil above the fossa should next be attacked.

The time necessary for coagulation varies from one to ten seconds, according to the strength of the current and the bulk of the tissue in contact with the electrode.

As a rule the above application is sufficient for the first séance.

Considerable difference exists among operators concerning the amount that should be coagulated at one sitting. Much, no doubt, will depend upon the size of the tonsil and the total length of time at our disposal, but more will depend upon the character of the patient. It is well, however, to proceed cautiously, at all events with the first applications, because of a certain tendency to reactionary pain and inflammation.

In this respect patients vary enormously. Some react vigorously, if not violently ; others little or not at all. As a rule the first applications are the worst.

Why it should be so is difficult to say. Perhaps it is because virulent organisms in the intact part of the tonsil are stirred up, by our intervention, into activity. Clinical phenomena at all events seem to favour this explanation, as pain, swelling and redness of the tonsil, with some œdema of the uvula, may appear, and even, though rarely, a transient rise of temperature to 100° or 101° F. Moreover, this local reaction is sometimes associated with a further general reaction, which takes the form, in arthritic cases, of a recrudescence of rheumatic pains and swellings. These last symptoms, however, may actually be welcomed, as they show that the tonsils are undoubtedly the source of infection, and so give promise that our treatment is likely to be beneficial.

After the early applications, however, reaction, whether local or general, ceases to appear. That being so, my practice generally is to be content with minor coagulations to begin with, and to reserve the more extensive interferences for the later occasions, when the patient has become accustomed, both physically and mentally, to the treatment.

After each séance the patient may be given a gargle of sol. aspirin (gr. x.—℥i aq.) for a day or two to soothe the soreness. The throat should be inspected a few days la when the white sloughs are conspicuous. Sometimes a certain amount of fœtor may be detected, but it seldom gives rise to any complaint. The sloughs disappear, partly by separation and partly by absorption, in the course of ten to fourteen days, and then the tonsils are ready for the next application.

If time is important we can, of course, intervene at shorter intervals, and in the same way the amount of tonsil destroyed on each occasion will vary according to circumstances. Speaking generally, however, we may say that, as in most operative procedures, a reasonable deliberation, when it can be obtained, enables us to proceed with greater comfort and satisfaction.

As the tonsils diminish in size they shrink behind the faucial pillars, where the operator may find some difficulty in approaching them. But their exposure may be contrived by hooking back the pillar, or the pillar itself may be diathermised so as to lay the buried part of the tonsil open.

The most inaccessible part and, as we have already pointed out, the part most liable to septic infection, is the upper pole. Now it is astonishing to anyone unaccustomed to tonsillectomy by dissection to find how deep into the lateral wall of the pharynx, and how high into the soft palate the tonsil, and more particularly its upper pole, can extend. And yet this is the part of the tonsil the destruction of which is most essential to success. The more completely it can be destroyed, therefore, the better.

The last remnants consist of what we may call "the capsular layer." By the time this has been reached the bed of the tonsil will be almost quite empty and the faucial pillars will have collapsed upon it, assuming that we have spared them. The capsular layer can be identified by the appearance of a network of rather thick trabeculæ of fibrous tissue separating small nodules of tonsil tissue from each other. To destroy these nodules the needle should not be pushed deep into or through the capsule, as thereby a blood vessel may be unnecessarily injured. All that is required is to make a shallow insertion of the point only into the centre of each of the small nodules. Not infrequently we may find it difficult to determine whether we have succeeded in getting rid of the bulk of buried tonsil tissue. In that case palpation of the tonsil bed with the finger may reveal isolated clumps that have escaped.

Once the capsular layer has been destroyed the tonsil bed should appear to be clean and smooth, and then we may consider our task completed, at all events for the time being.

As to the number of séances necessary, together with the total duration of the treatment as a whole, matters the patient is always naturally interested in, these vary from five or six, occupying two or three months, up to as many as twenty. Much depends upon the size of the tonsils, but more upon the patient's reaction. Later applications, however, are superficial and trifling, consisting as they do merely of a number of needle-pricks. On an average, six or eight séances at fortnight intervals seem to be sufficient for most cases.

### Results

Apart from the reactionary phenomena we have already considered, one striking effect may be observed after the third or fourth application, namely, a general improvement in the patient's symptoms, particularly in subacute rheumatic cases. The pains disappear or become much less severe; the swellings subside. This occurs so regularly that I have come to regard its absence as an unwelcome indication that the tonsils are innocent. As an unexpected sequel of this occurrence we may find that the patient, considering himself cured, declines to submit to any further interference. But to call a halt with the bulk of the tonsils still present leaves the door open for further attacks. What has happened probably is, as I have pointed out on a former occasion, that the diathermy sterilises directly by its heat, or indirectly by some sort of local reaction, the tonsillar tissue proximal to the line of actual coagulation, so that toxic absorption ceases for the time being. But if sufficient tonsil tissue be left *in situ*, sooner or later it will become re-infected and symptoms will recur. Experience shows, however, that this event may be delayed for quite a long time. Thus in a recent case the patient, who had had his tonsils partially diathermised for recurrent tonsillitis, remained free from symptoms for four years. Then they reappeared. When recurrence takes place it will sometimes be noticed that the tonsil remnants become red and irritable-looking and undergo an increase in size.

This observation shows the importance of eradicating all tonsil tissue. At the same time, however, it must be confessed that the absolute and entire destruction of all tonsil tissue by diathermic coagulation is often both tedious and difficult. In this respect it contrasts with surgical dissection or enucleation, since that operation can give the surgeon and his patient the comfortable assurance that the tonsils are completely extirpated and that toxæmia therefrom is consequently entirely eliminated.

But here we come upon one of those surprises in which the practice of medicine is so rich.

In the first place, toxic symptoms may in fact be permanently banished by diathermy, even although some clumps and islets of tonsil tissue do escape destruction. It would appear that, when the bulk of the tonsil has been removed, subsequent septic infections of trifling remnants may be ignored.

In the second place, the comfortable assurance imparted by tonsillectomy, alluded to above, may turn out to be nothing better than a comfortable delusion. Lymphoid tissue is indestructible. It may be punctiliously removed from one site only to reappear in its immediate neighbourhood. Tonsils may be radically removed, and yet in ten years' time the faucial pillars and the lateral pharyngeal wall may be found studded and thickened with a large number of lymphoid nodules, and they may become as liable to septic infection as the original tonsils !

This development does not occur in every case fortunately, but its occasional appearance rather detracts from the value of the argument in favour of tonsillectomy as opposed to diathermic destruction, and this even although recurrence of toxic symptoms is, when all is said and done, more likely to follow imperfect diathermisation than perfect tonsillectomy.

The practical rule may perhaps be expressed as follows. When toxic symptoms have been banished by diathermy, the destruction of the tonsil should be carried down to include the capsular layer of the tonsil, but the persistence of a few islets will probably be harmless. That is to say, as in all operative therapy, we should judge by the results as manifested in our patients, and not by the radical thoroughness of our operation. It is not wise to be entirely dominated by logic.

Further, if, as in the case referred to above, a virulent sepsis is arrested for some years and then recurs, diathermy may be used again with every prospect of a repeated success. Not only so, but also in the lymphoid regeneration occasionally seen after tonsillectomy, the application of diathermy to the inflamed nodules will be found quite useful.

To conclude this discussion, the warning may be given, however, that the less tonsil tissue there is left behind after diathermy the more lasting is the benefit likely to be and the less likelihood there will be of a tonsillectomy being resorted to after all.

### Cicatrisation

Provided care be taken to avoid as far as possible diathermising connective and fibrous tissues and to confine the destructive process strictly to the tonsils, the scars that subsequently form will be thin, smooth, and almost invisible, in contrast, we may say, with what takes place after extensive diathermic excisions, as for carcinoma of the tonsil. Moreover, if the same care be exercised, the drawback to the use of the ordinary galvano-cautery, of closing the orifices of crypts with scar-tissue, will never be encountered.

## Complication

The only *complication* of treatment by diathermy coagulation that is left for us to consider is that of hæmorrhage during the separation of the sloughs. I may say that if the method of operating described above be followed, the risk of serious bleeding is slight. So far I have not myself encountered a single case in which it necessitated treatment. This escape may be attributed to cautious coagulation in depth. I am well aware that there are operators who diathermise with greater boldness, and I have heard of cases in which subsequent bleeding called for intervention.

In such an event, direct pressure by means of a gauze swab on a sponge-holder maintained for about half an hour will probably arrest the bleeding. If not, the tonsil-clamp, a reliable but uncomfortable instrument, may be applied for several hours. If even that fails, it may be necessary to dissect out the tonsil under general anæsthesia in order to ligature the bleeding points—a difficult undertaking in the midst of diathermy sloughs. The final resource is ligature of the external carotid artery in the neck, assuming that the diathermic electrode has not happened to wound the internal carotid !

Thus, unless an operator is confident of his ability to deal successfully with serious tonsil hæmorrhage, he ought to use diathermy with care, avoiding large and dashing coagulations and excisions, and being particularly cautious as he approaches the capsule of the tonsil. If, however, these precautions are observed, diathermising the tonsils, even to their ultimate recesses, seems to be free from the danger of hæmorrhage.

As a measure of safety it is advisable to insist that the patient should reside within easy reach of the surgeon during the separation of the sloughs—that is to say, from the tenth to the fourteenth day after the application.

## Conclusion

As we have already remarked, not every case of apparent tonsil sepsis will benefit by tonsil removal, whether by operation or by diathermy. But when it is successful the results are very pleasing both to patient and to surgeon. The first case I ever tried diathermy on was that of an old gentleman crippled with rheumatism to the extent that he could only hobble about on sticks. Yet in four months he was playing golf, and the benefit continues to this day. Another of my cases (shown before the Section of Laryngology of the Royal Society of Medicine) was that of a young woman with moderately severe exophthalmic goitre. Every six months or so she ran the risk of losing her life from acute tonsillitis with high temperatures. The tonsils were very large and the patient's general state forbade tonsillectomy by dissection. Diathermy was employed with every precaution, and the tonsils were gradually destroyed. This was done with the object of removing the risks of sepsis and also of rendering her capable of subsequently facing a thyroidectomy. But to our astonishment not only was the tonsillitis got rid of, but the thyrotoxicosis diminished so greatly that operation on the thyroid proved to be unnecessary. She also remains well.

We may therefore claim that diathermic destruction of the tonsils is a welcome addition to our therapeutic resources. But it should be used with discrimination.

# CHAPTER XLIV

# ELECTROTHERMIC METHODS IN THE TREATMENT OF PROSTATIC OBSTRUCTION

BY

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## History

THE modern treatment of certain cases of prostatic obstruction by means of such an instrument as the McCarthy resectoscope is but a stage in a long series of advances towards an ideal. From the time that Guthrie realised that there existed cases of bladder obstruction unassociated with massive enlargement of the prostate gland, surgeons have been endeavouring to get rid of that obstruction by some form of per-urethral operation. Innumerable workers have striven towards that goal. Civeale's and Mercier's urethrotomes, Bottini's electro-cautery, Young's prostatic punch (see Fig. 156), and Caulk's cautery punch must all be regarded as stepping-stones that lead up to the per-urethral methods of dealing with prostatic and bladder-neck obstruction in vogue at the present moment. It was, however, only after the application of the high-frequency current to the treatment of bladder papillomata by Beer, in 1910, that what had previously been a distant ideal came within the reach of practice. Certain workers, and notably Stevens and Bugbee in America, and Luys in Paris, impressed with the value of

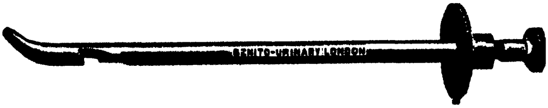

FIG. 156.—Young's original Prostatic Punch.

"fulguration" in the bladder, extended the same method to the region of the bladder neck. Stevens' earliest report in 1913 was based on 2 cases, 1 of contraction of the bladder neck and the other of enlargement of the median lobe of the prostate. To both were applied diathermy by means of an electrode working through an operating cystoscope. The results were excellent and the amount of discomfort suffered by the patient minimal.

A year later Luys reported successes with a method of endoscopic electrocoagulation which he termed "forage de la prostate." He used a simple endoscopic tube bearing a lamp on the end of a long arm and, under direct vision, applied a rigid electrode to the obstruction, his object being to hollow out a channel in the prostate through which urine could flow. Luys' methods for a long time passed unnoticed, surgeons being inclined to regard them as ineffectual and even mischievous. Nevertheless, other workers began to discover the value of electrocoagulation in selected cases of minor prostatic obstruction and from time to time published papers on the subject. Improvements in the design of operating cystoscopes and cysto-urethroscopes brought the procedure within the capacity of a greater number of operators, and electrocoagulation of the prostate established itself as a recognised method of treatment applicable to a strictly limited number of cases.

In 1925 the writer in association with Mr. R. Schranz, of the Genito-Urinary Manufacturing Company, brought out the first diathermy punch. Having employed Caulk's instrument and encountered difficulties owing to the variation in the type of current in use in different parts of London, I discussed the matter with Mr. Schranz and together we conceived the idea of using, in conjunction with a punch, diathermy instead of the electro-cautery. The new instrument marked an important step in per-urethral methods, not only because it combined diathermy with a punching operation, but also because in its manufacture bakelite was for the first time employed as an insulating material (see Fig. 157). A further advance was achieved by Stern in the following year by the introduction of a new loop type of resectoscope. With this instrument, spaghetti-like sections of tissue could be cut from the prostate by means of a small multiple loop of tungsten wire activated by a suitable current. Stern's invention led to the design of many new

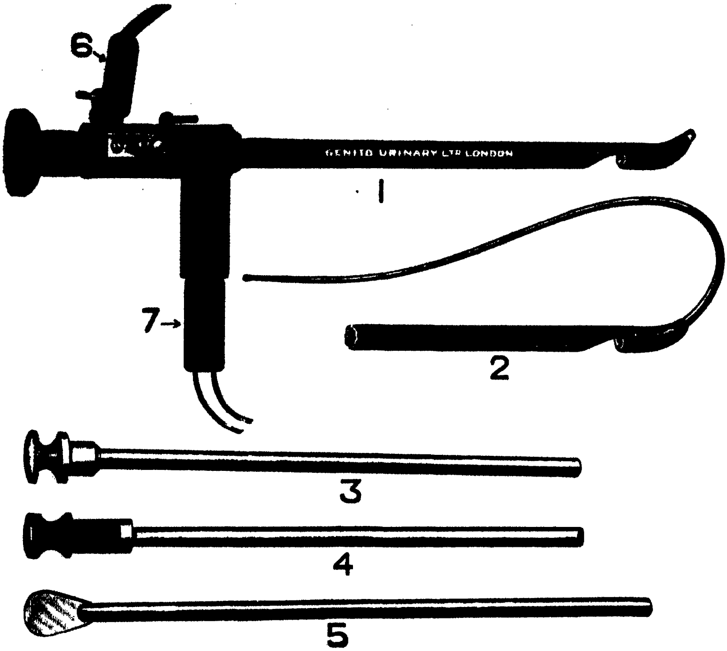

FIG. 157.—Writer's Original Diathermic Punch.

1. The Punch with its insulating cover of bakelite.
2. Punch with pliable bougie attached to its extremity to act as a guide to its introduction.
3. Obturator.
4. Inner tube for punching out coagulated tissue.
5. Obturator for removing core of coagulated tissue from the Punch.
6. Current for light.
7. Connection with source of diathermic current.

instruments, and per-urethral resection of the prostate became firmly established.

## Modern Per-urethral Methods of Treatment

Although a great many different techniques are employed at the present day in the treatment of prostatic and bladder-neck obstruction, they may all be classified for convenience in description under the following headings :—

(1) Diathermic coagulation with an electrode working through a cysto-urethroscope, the operator leaving the coagulated tissue to slough away subsequently.

(2) Diathermic coagulation, with immediate removal of the coagulated tissue by means of a punch.

(3) Resection of the prostate by a wire loop activated by means of a *cutting* current.

### (1) *Diathermic Coagulation, without Removal of the Coagulated Tissue*

This, the oldest method of treatment, is also the simplest. All that is required to carry it out is some form of operating cystoscope, or cysto-urethroscope provided with facilities for continuous irrigation. The instrument selected will depend on the individual preference of the surgeon, the writer employing McCarthy's Panendoscope (Fig. 158) or a Wolff's pattern of cysto-urethroscope or, in cases in which the urethra would not admit an instrument of so large a calibre, the Ogier-Ward operating cysto-urethroscope made by the Genito-Urinary Manufacturing Company. In many cases the ordinary electrode, such as is used in the coagulation of bladder growths, is sufficient for the purpose. Sometimes, however, it will be found to be too pliable and

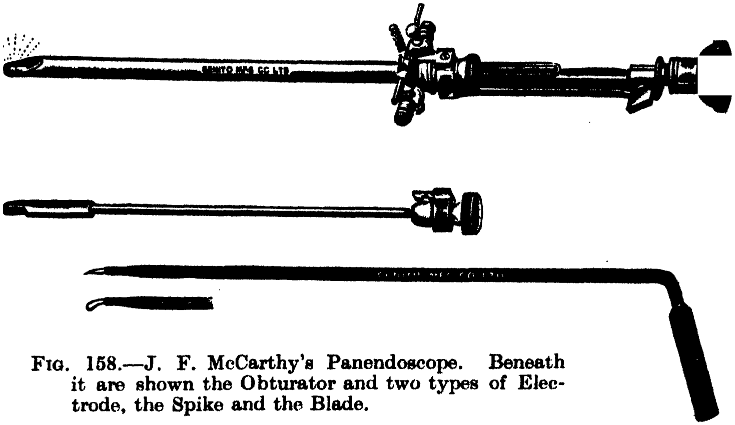

FIG. 158.—J. F. McCarthy's Panendoscope. Beneath it are shown the Obturator and two types of Electrode, the Spike and the Blade.

a more rigid electrode, and preferably one that ends with a spike, more suitable. The fact that the spike can be driven into the substance of the prostate allows of coagulation being carried out not only on the surface but in the depth of the obstructing mass. This will mean that more tissue is destroyed and a deeper channel dug. With this form of electrode the operator works from the urethral aspect of the obstruction towards the bladder. In the opinion of C. Collings this is an objection, and in order to overcome it he has designed an electrode ending in a blade set at an angle with its insulated sheath. With this electrode he claims that he can cut out V-shaped sections from an obstructing middle lobe and remove more tissue than would otherwise be possible. The writer is not able to substantiate this claim, and feels that the advantages of easy introduction possessed by the spike electrode make it a preferable weapon.

### (2) *Diathermic Coagulation, with Immediate Removal of Coagulated Tissue by Means of a Punch*

It is obvious that, other things being equal, much is to be gained by the immediate removal of the coagulated tissue. Not only does this confer on the patient immediate benefit from his operation, but it also materially diminishes the risk of sepsis.

There are many different forms of diathermic punch now in use, but the principle underlying most of the instruments is the same, namely, coagulation by means of an electrode and subsequent removal of the coagulated tissue by a circulating knife. Probably the best-known patterns of instruments are the Kirwin, Davis and the Bumpus punch. The disadvantage, however, of these instruments is that a circular knife to which a single movement of advance is imparted may fail to cut through the engaged tissue. It is true that in the Bumpus punch, a double movement can be used by imparting to the inner cutting tube a lateral as well as an antero-posterior movement. Nevertheless, unless great care is taken to do this, the coagulated tissue may be pushed aside rather than cut through. For this reason the spiral punch designed by the Genito-Urinary Manufacturing Company has a definite advantage over other patterns, on account of the fact that the inner punching tube works in a spiral groove so that a lateral movement is inevitably imparted to the forward one when it is brought into action. The inner system of this instrument consists of a telescope of the McCarthy type carrying a lamp, an electrode terminating in a point, and irrigating channels with stop cocks (see Fig. 159). The tubular knife when closed acts also as an obturator. Once the punch is in position, the window is opened, the bladder distended and the obstruction located.

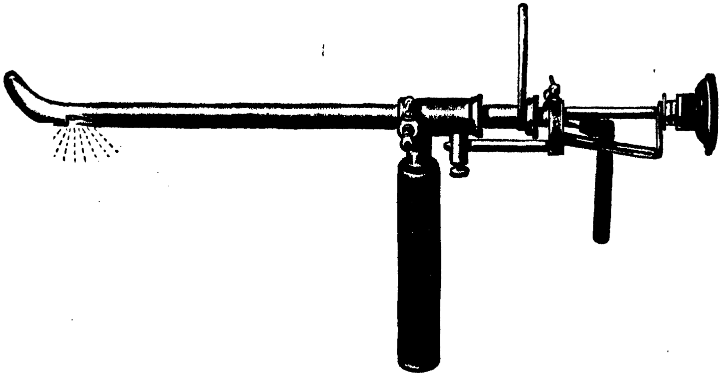

FIG. 159.—Spiral Punch fitted with Foroblique Telescope and Spike Electrode.

The obstructing portion of the prostate is then engaged in the window cut in the posterior aspect of the punch, transfixed with the spike electrode and coagulated under low heat for about thirty seconds. At the end of this period the coagulated area is punched out by advancing the tubular knife. The process may be repeated as often as is necessary for complete removal of the obstruction, the resected tissue being withdrawn each time by removing the knife and the inner sheath with its attachments and leaving the outer sheath in position.

## (3) *Resection by Means of a Cutting Current*

This operation has a definite advantage over the former one. One of the difficulties when employing coagulation followed by punching is that the operator is unable to judge accurately how much coagulation must be carried out before punching. Usually considerably more tissue is coagulated than is subsequently removed, and this excess remains as a nidus for organisms. The activated tungsten loop punches out at the same time as it seals off the blood vessels in the neighbourhood of the cut, so that the amount of injury inflicted on the tissues that remain is minimal. Caulk, in supporting the advantages of the electro-cautery over the high-frequency current in resection of the prostate, states that with the latter great heat may be developed in the tissues at even a centimetre's distance from the loop. He asserts that this constitutes a definite danger in operating with the high-frequency current and is probably the cause of complications like severe sepsis, recto-vesical fistula, etc. Certainly Caulk's warning must be kept in mind, but if the area of operation be changed at each successive cut so as to avoid the risk of accumulative heating, the danger of massive necrosis of the tissues is, in the writer's opinion, not very serious.

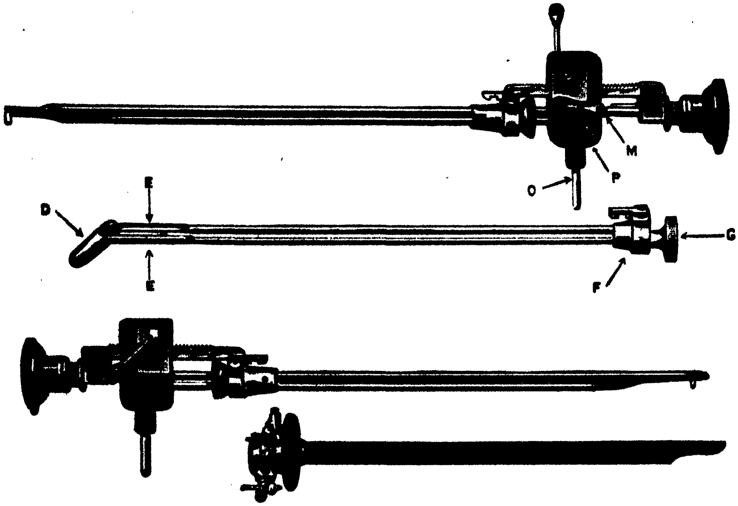

FIG. 160.—The McCarthy Prostatic Electrotome.

The best instrument of the type that depends on the cutting action of a current in a tungsten loop is undoubtedly the McCarthy electrotome, or one of its numerous modifications (Fig. 160). This consists of a straight outer sheath that is made of bakelite and is inserted into the bladder by means of an elbowed obturator. The distal end of this sheath is cut away so that the loop is free to engage the obstructing portion of the prostate. After evacuating the bladder of any residual urine and washing it out, the inner system, consisting of a foroblique telescope, a lamp, an irrigating channel, and a movable tungsten loop, is inserted. The inlet tube is then connected up with a large reservoir of sterile water in order that constant irrigation may be maintained during the whole of the operation. It is important that sterile water be used instead of any antiseptic lotion, since the cutting power of the loop is reduced by an escape of current if it is surrounded by a good conductor. Having located the obstruction to be removed, the instrument is advanced into the bladder until its upper edge alone remains in the field of view. This is necessary in order that the loop may be pushed beyond the obstruction into the cavity of the distended bladder without risk of damaging it. When the loop is judged to be at the right depth and situation, the cutting current is turned on by means of a foot switch and the loop is withdrawn by the movement of a rack and pinion. The movement should be a steady and slow one, a cut of an inch in length taking ten to fifteen seconds to make. In order to obtain as large a piece of tissue as possible it is advisable to raise the proximal end of the instrument so that in the case of a large prostate the loop has entirely disappeared from view behind the obstruction. After the cut has been made the loop is removed so that the adhering cylinder of resected tissue may be abstracted from it by means of dissecting forceps. The operation is then repeated until the required amount of tissue has been resected. If difficulty is found in engaging the obstruction towards the end of the operation, help may be obtained by an assistant pressing forward the prostate with a finger in the rectum. Should bleeding become excessive and obscure the field of view a ball electrode may be substituted for the loop and a *coagulating* for a cutting current, so that bleeding points may be sealed off. The loop may be used for the same purpose in conjunction with a regulating current, but always at the risk of damaging it. For this reason it is better to expend the few minutes necessary for exchanging the one type of electrode for the other.

A ball electrode and a loop electrode are illustrated in Fig. 161.

### Pre-operative and Post-operative Treatment

The same care must be exercised in testing the renal function and in preparing the patient for operation that is customary before a prostatectomy. Although the per-urethral method throws less strain on the patient and is accompanied by much less shock, renal complications are always dangerous. However skilfully the operation is carried out and however careful the after-treatment, a certain amount of sepsis must inevitably follow, and sepsis in the lower urinary tract in the presence of damaged kidneys is always to be feared. When the amount of residual urine is considerable a preliminary drainage of the bladder will generally be required, either through an in-dwelling catheter or, where more prolonged preliminary preparation is necessary, through a suprapubic tube.

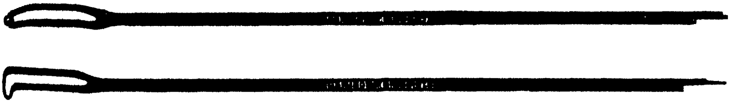

FIG. 161.—The two types of Electrode for use with the McCarthy Electrotome, the Ball and the Loop. The Ball is used for coagulating, the Loop for cutting.

Per-urethral operations can be performed under low spinal, trans-sacral or caudal anæsthesia. Of these three methods, a low spinal has the widest application and is the easiest to carry out. When the patient is nervous or dislikes the idea of being conscious during the operation a general anæsthetic may have to be given.

The post-operative treatment is the same whatever technique has been employed. In the majority of cases provision must be made for drainage by means of an in-dwelling catheter. The best type for this purpose is a rubber whistle-ended catheter with large lateral openings (see Fig. 162). This catheter can be inserted through the sheath of the electrotome before it is withdrawn. The length of time that the catheter must be left in position will vary in different cases, depending on the amount of residual urine, the quantity of prostate removed and the existence or not of post-operative bleeding. Frequently the catheter may be removed within a few days of the operation. Sometimes, however, it will be found that the patient does not begin to pass water satisfactorily for two or three weeks. Where considerable enlargement of the prostate exists, it may well be found that the amount of tissue removed has been insufficient and that a second session is required. There is a growing tendency amongst resectionists to avoid massive removals at one session and to have recourse to several sittings. This policy is a wise one, since it reduces the risk of perforating the bladder wall during the later and more difficult stages of the operation when bleeding is likely to obscure the view, and the exact position of the loop is more difficult to locate. It is better therefore to explain to the patient with a considerable obstruction that the resection may have to be repeated before a satisfactory result is obtained.

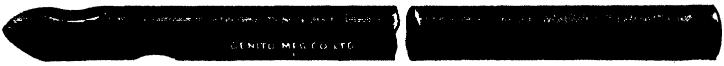

FIG. 162.—Rubber Whistle-ended Catheter for Per-urethral Drainage after Operation.

In order to guard against sepsis—the complication most to be feared—an in-dwelling catheter should be connected up with a St. Mark's Hospital irrigating apparatus, by means of which the bladder can be flushed out at hourly intervals. In other cases it will be sufficient to instil twice daily a few drachms of weak protargol or argyrol. Where there has existed the dangerous combination of a large amount of residual, considerable sepsis and markedly deficient kidneys, I have no hesitation in inserting a temporary supra-pubic drain. The same step has also been taken in cases in which the patient refuses to tolerate catheterisation. Once the patient has begun to pass urine satisfactorily all that is necessary is to pass a catheter occasionally in order to estimate the residual urine.

Some enthusiastic advocates of per-urethral resection have gone so far as to state that the method carries with it no risk or, at any rate, one that is negligible. This is an error, for not only must any operation on the class of patient in which per-urethral resection is often performed necessarily carry with it some degree of risk, but the operation can never be regarded as a minor one. In unskilful hands a McCarthy loop is capable of doing a great deal of damage, and cases of perforation of the bladder, extravasation of urine and rectal fistula are by no means uncommon. That the personal skill of the operator is an important factor is revealed by an examination of statistics. These generally show that with an increase of experience on the part of the operator there is a steady fall in the death rate. But statistics can never give a very accurate indication of risk, since the figures will depend on the cases selected by the operator and his willingness or not to tackle unpromising material. All that can be said is that in the hands of an expert, prostatic resection is associated with a death rate well under 5 per cent.

### Selection of Cases

The keynote to success in per-urethral work lies in the careful selection of cases. It is because the method has been abused and applied indiscriminately that it has fallen into disrepute in certain quarters. Per-urethral resection is not a general substitute for prostatectomy ; it is a method of treatment that is applicable to special types of case or to special circumstances. Speaking broadly, it may be said that the special type of case to which it is applicable is where the amount of enlargement is small although the obstruction may be great. More especially is it indicated when it is the vesical rather than the urethral aspect of the prostate that is affected, and the middle lobe rather than the lateral. It is also the operation of choice in cases in which the obstruction is due to an increase of fibrous tissue in the region of the bladder neck, that is, to cases that come under the terms of sclerosis of the bladder neck, sclerosing atrophy of the prostate and fibrous prostate. It is also an extremely useful alternative to permanent suprapubic drainage in cases of malignant disease of the prostate. The special circumstances in which resection may be used are where for some reason or other a total removal of the prostate is contra-indicated, either because the general condition of the patient is poor because he is suffering from some serious cardiac, pulmonary or renal lesion, or because he refuses to face the risks and discomforts of a total prostatectomy. It should be borne in mind, however, that in the last-named type of case, the relief of obstruction may not be complete, or even if complete, may only be temporary. The lack of permanency in the benefits obtained is, however, not so serious a drawback as at first sight may appear, for a patient who has undergone the operation once and discovered that it is associated with comparatively little pain or discomfort, will easily agree to a repetition of the procedure when the further growth of the prostate leads to a return of symptoms.

## Current Generators

The current generators used in per-urethral operations will depend on the personal bias of the operator. Some authorities have definitely shown a preference for machines of the valve type over those of the spark gap type. The writer employs the G.U. diathermic apparatus with fixed spark gaps made by the Genito-Urinary Manufacturing Company (see Fig. 109). This instrument has the advantage of being sufficiently portable to be transported in a private car. Its current consumption is 0·8 K.V.A. of alternating current of 50 cycles. The transformer is designed to work on any alternating supply mains from 100 to 240 volts. The two spaces in the spark gap are bounded by metal, fitted with tungsten discs and air cooled. They are mounted in series, and since the sparking distance is not adjustable they need practically no attention. The oscillation frequency is variable and ranges from $2{\cdot}5 \times 10^6$ to $6 \times 10^6$ cycles. For the purpose of adjustment this scale of frequencies is roughly divided into two by means of a capacity switch with two positions, marked " Diathermy " and " Cutting." The lower range of frequency is used for coagulation (diathermy), whilst the higher produces a perfect low voltage cutting (endothermy) effect. The fine adjustment of frequency and strength of current is obtained through an inductance regulator mounted in the centre of the ebonite panel with a scale varying from 0 to 10. This scale on the inductance regulator is empirical; the optimum position depends largely on the nature of the tissues to be cut and the type of electrode that is used. The apparatus is controlled by the operator himself by means of a foot switch.

## Other Forms of Technique in Prostatic Resection

The operations described in the present chapter are those of which the writer has the most experience and which in his hands have been found to be most practicable. Once having mastered a satisfactory technique nothing is to be gained by multiplying methods. Nevertheless, it must be remembered that a great many different designs of electrotome and punch are at the present time being used, and for the sake of completeness some reference must be made to them.

At the Mayo Clinic, where over 80 per cent. of cases of prostatic enlargement are at present being dealt with by per-urethal methods, the instrument generally employed is the Bumpus punch. This consists of a metal outer sheath with a window cut in the convex surface just below the elbow (see Fig. 163).. The lamp is carried in the beak of the instrument, the operation being done under direct vision. After the introduction of the instrument the obturator is removed and the obstruction engaged in the window. Coagulation is carried out by transfixing the obstruction with a five-pronged diathermic electrode. When it has been completed the coagulated tissue is punched out by means of a circular inner cutting tube. If bleeding is excessive it is dealt with by inserting a special system through which an ordinary flexible electrode can be introduced.

Another popular model of electrotome in America is the Kirwin rotary resectoscope. It consists of an outer steel sheath with a fenestra on one side and a beak on the other, and an inner tubular structure which carries the McCarthy lens system, a high-frequency needle and irrigating cocks. A specially important feature is the tubular knife which rotates between the two sheaths and acts at the same time as an obturator. The electrode, by means of which preliminary coagulation is carried out, acts also as a Luer needle

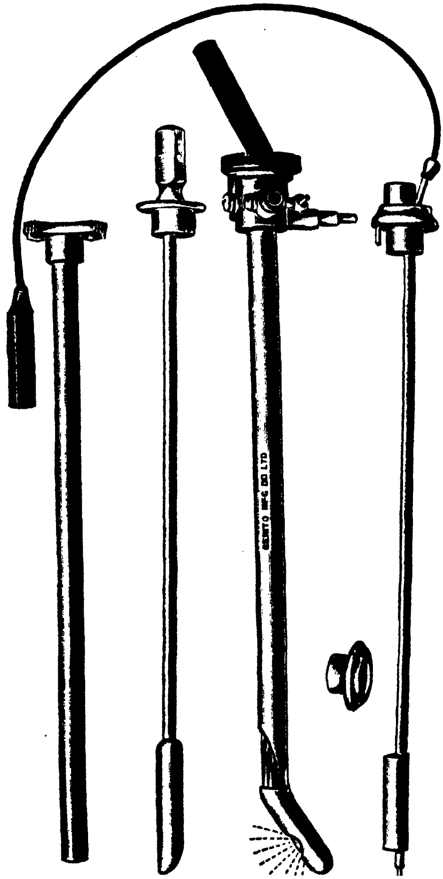

FIG. 163.—The Bumpus Punch, showing Tubular Knife Obturator, Cystoscope with Multiple Spike Electrode, and special system for use with Flexible Electrode.

through which the area to be removed can be anæsthetised by a preliminary injection of novocaine. The obstructing tissue is firmly fixed by the needle electrode and desiccated under low heat for about thirty seconds. It is then resected by rotating the tubular knife, the withdrawal of which removes the resected tissue leaving the outer sheath in the urethra. Kirwin has lately modified his original instrument, the chief features of the new design being a bakelite insulating sheath and a rotary loop by means of which tissue can be cut and coagulated under direct vision.

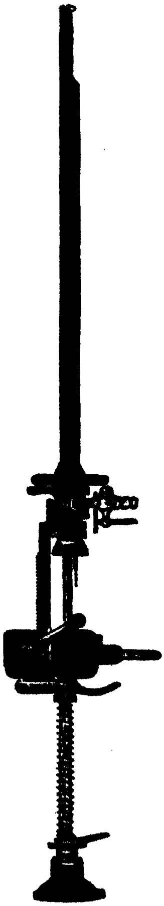

FIG. 164.—Ogier Ward's modification of McCarthy Electrotome. In this the Telescope can be moved independently of the Sheath, and by this means the size of the Prostate can be more accurately determined.

Since McCarthy introduced his transurethral electrotome it has been modified in various ways by different workers. Thus Mr. Ogier Ward has produced an instrument which possesses several advantages over the original (see Fig. 164). In his modification, the telescope can be moved independently of the sheath and of the cutting loop. This independent mobility overcomes a difficulty that is sometimes experienced, namely, that of knowing the exact position of the loop before the cut is commenced. This is certainly an asset during the later stages of the operation when visibility is impaired and the anatomy of the bladder neck altered by the previously made cuts. Should the operator not be able to locate accurately the position of his loop, the telescope can be advanced into the bladder so as to locate it. When the desired information has been obtained the telescope is released and automatically clears itself so that no electric short is possible. The independently moving telescope has a second use. Before beginning the treatment of prostatic enlargement it is desirable to have some record of the size of the gland. One important measurement is that of the length of the prostatic urethra from the verumontanum to the crest of its intravesical projection. To measure this the sheath is placed so that the verumontanum is just visible ; in this position it is held steady and the telescope is then advanced until the bladder entrance is reached, each centimetre of movement being recorded by a notch.

When the measurement has been recorded a further use may be made of it if desired. The instrument can be set to make a definite length of cut on each occasion, the setting chosen being obviously always less than the total length of the prostate above the verumontanum. This ensures that each cut that is made is never of dangerous length.

# CHAPTER XLV

## SURGICAL ELECTROTHERMIC METHODS IN NEOPLASTIC DISEASE OF THE URINARY BLADDER

### Evolution of the Treatment

To Edwin Beer, of New York, belongs the credit of suggesting the use of high-frequency currents for destroying intra-vesical neoplasms and of devising a method of performing the operation by way of the urethra. In 1910 he contributed a paper to the *Journal of the American Medical Association* (liv., 1768), entitled " Removal of Neoplasms of the Urinary Bladder." In 1912 he wrote another paper for the same journal (lix., 1784), " Treatment of Papillary Tumors of the Bladder with the High-frequency Current."

Edwin Beer employed the high-voltage current from an Oudin resonator attached to a Wappler high-frequency machine. As an active electrode he used a six-ply cable of copper wire, suitably insulated, and cut off squarely at the end which was applied to the growth. He filled the bladder with distilled water. A cystoscope was passed and the free end of the electrode introduced a short distance in among the villi. The current was passed for fifteen to thirty seconds. Gas was seen to emerge freely from the growth. If the free end of the electrode were placed just in contact with the villi the latter were observed to whiten. Continuation of the current caused the tissue in contact with the electrode to darken and become black, as if it were carbonised.

In 1913 French workers (André, Heitz-Boyer, Legueur, Lepoutre, d'Halluin) employed the high-frequency current from the d'Arsonval machine for the coagulation (electro-coagulation) of growths of the bladder. In the same year German and Austrian operators (Bucky, Casper, Goldberg, Schneider, Stein) contributed papers on the coagulation of bladder growths by the diathermic current.

In the *Clinical Journal* of April 15th, 1914, is a description of a demonstration by Frank Kidd, at the London Hospital, of the treatment of a case of papilloma of the bladder by diathermy. Andrew Fullerton, of Belfast, described the treatment of 2 cases in the *British Medical Journal* (November 14th, 1914). The two last-mentioned surgeons used a portable high-frequency current generator made by Loewenstein, of Berlin. This apparatus had been demonstrated at the International Medical Congress held in London in 1913.

After the European War (1914–18) the use of electrothermic methods in the treatment of papillomata of the bladder was generally adopted by urologists in this country. Their treatment by electrocoagulation was specially studied by W. Girling Ball. Those who are interested in the subject should consult a paper contributed by him to the *British Journal of Surgery* for 1924, No. 44. There was no recurrence of hæmaturia or reappearance of the growths in the cases which were kept under his observation and examined with the cystoscope from time to time. Some of his cases were examined six, seven or eight years after operating.

At the present time diathermic coagulation is widely practised in the treatment of these papillomata. The advantage gained by the use of this method is the freedom from recurrence. The growth of fresh papillomata was frequently observed after operation by the scalpel. Untoward events of this kind rarely occur after electrocoagulation.

## Methods of Treatment by Diathermic Coagulation

For the application of diathermy to the papillomata two electrodes are required. One, the *indifferent* electrode, is placed on some distant part of the body. The other, the *active* electrode, is brought into contact with the growth, either by way of the urethra or through an incision in the hypogastrium and the bladder wall. If the growth is approached by the urethral route a cystoscope and a special active electrode are required. The papillomata are coagulated piecemeal and allowed to slough away.

### (1) *Operation by the Urethral Route*

The active electrode consists of a narrow springy wire covered, except at its ends, by waterproof insulating material. One end terminates in a short platinum rod with a rounded end. The other extremity is provided with a connection for attachment of the cable from the diathermic machine. This electrode is passed along the side channel of the cystoscope.

The indifferent electrode is a metal plate measuring about 8 in. by 4 in. It is placed on the patient's abdomen with a pad soaked in strong salt solution intervening between the metal and skin.

If the patient is not given a general anæsthetic the urethra is rendered insensitive with cocaine. An irrigating cystoscope is passed and the bladder washed clear. The active electrode is passed into the side channel of the cystoscope until its platinum tip lies within the bladder. The bladder is now filled with about 12 oz. of sterile water and a papilloma brought into view. The electrode is manipulated until its platinum tip makes contact with the base of the papilloma. If the base is hidden from view by overlying fimbriæ the tip of the electrode is brought into contact with them first. The current is started and gradually increased. The tissue in contact with the electrode is observed to whiten from coagulation. The current is now stopped and the electrode brought into contact with another part of the papilloma. The process is repeated until the overlying fimbriæ have been coagulated.

After a few applications of the current the water in the bladder becomes cloudy and obstructs the view of the operator. The irrigation must then be repeated. Coagulated portions of the papilloma escape with the irrigating fluid. The bladder is then refilled with water and the current re-applied to the remaining parts of the growth or to other papillomata.

A small area of the mucous membrane around the base of each papilloma is also coagulated.

If it is not possible to treat all the papillomata at one operation, an interval of not less than fourteen days is allowed to elapse before repeating the treatment.

At the end of the operation the bladder must be thoroughly washed out. If any particles of uncoagulated growth remain within the bladder there is a likelihood of the growth of new papillomata.

It is seldom necessary to keep the patient in bed for more than a day or two. For a few days after the operation small sloughs separate and escape with the urine. Occasionally a little bleeding occurs during this time.

### (2) *Operation by the Supra-pubic Route*

When the bladder is opened through an incision in the hypogastrium the mucous membrane around the papilloma is covered with wet gauze in order to prevent any separated particles of the growth from falling on the healthy lining of the bladder. The papilloma is grasped below its fimbriæ by suitable forceps. The fimbriæ should not be included in the grip of the forceps for fear of the separation of tumour cells. If the papilloma is pedunculated a right-angle forceps may be used to grasp the pedicle. Slight traction is exercised on the latter so as to pull the mucous membrane of the bladder a little distance away from the muscular coat. A blade electrode is now used to perform the combined coagulating and cutting operation through the healthy mucous membrane around the base of the pedicle. In this way the papilloma and the healthy tissue for a short distance around the base of the pedicle are removed.

If the growth is sessile the healthy mucous membrane around its base should be grasped by a ring forceps. The papilloma is then drawn a slight distance away from the muscular coat and the mucous membrane coagulated and cut as stated above.

If the growth is sessile and the mucous membrane at its base cannot be grasped by the forceps, the blade electrode is first used to incise the mucous membrane around the base of the growth. The edge on the inner side of the incision is grasped by a forceps and the blade electrode used to coagulate and cut through the healthy mucosa below and around the growth.

Malignant disease of the urinary bladder is unsuitable for treatment by diathermy. Malignant papillomata are difficult to distinguish from benign growths by cystoscopic examination. If the former are treated by diathermy in the same manner as the latter they quickly reappear.

# CHAPTER XLVI

# SURGICAL ELECTROTHERMIC METHODS IN OPHTHALMOLOGY

BY

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## Therapeutic Field

Surgical diathermy (electrocoagulation) is employed in ophthalmology in the treatment of simple detachment of the retina; in the removal of neoplasms of the lid, conjunctiva and orbit; in the treatment of symblepharon arising in a contracted socket; for the relief of trichiasis; and it is under trial for intracapsular extraction of cataract.

### DETACHMENT OF THE RETINA

The fundamental principles in the treatment of simple retinal detachment are briefly as follows: Localisation of the site of a retinal tear or hole and the effective closure of this by exciting a choroido-retinitis in its vicinity and draining the inter-retinal (sub-retinal) fluid during the period in which adhesions are forming.

Before operation a careful search for a retinal tear or hole is made and its meridional position estimated in terms of the hands of the clock, its distance from the ora serrata being calculated in optic disc diameters (the approximate diameter of the optic disc being regarded as 1·5 mm.). Retinal holes may be single or multiple, situated in the detached portion of the retina or remote from it; their shape may be round, arrow-headed or slit-like. Large irregular rents and extensive tears at the ora serrata (anterior retinal dialysis) are sometimes seen.

Surgical diathermy is used to excite a localised choroiditis over the site and in the vicinity of the retinal tear and detachment. Beneath the points of application to the sclera, lymphocytes, plasma cells and fibroblasts appear in the underlying choroid and small buds of granulation tissue herniate through Bruch's membrane, grappling the retina to the choroid and ultimately being replaced by fibrous tissue, thus making a secure choroido-retinal adhesion. To date, three methods of achieving this object are practised.

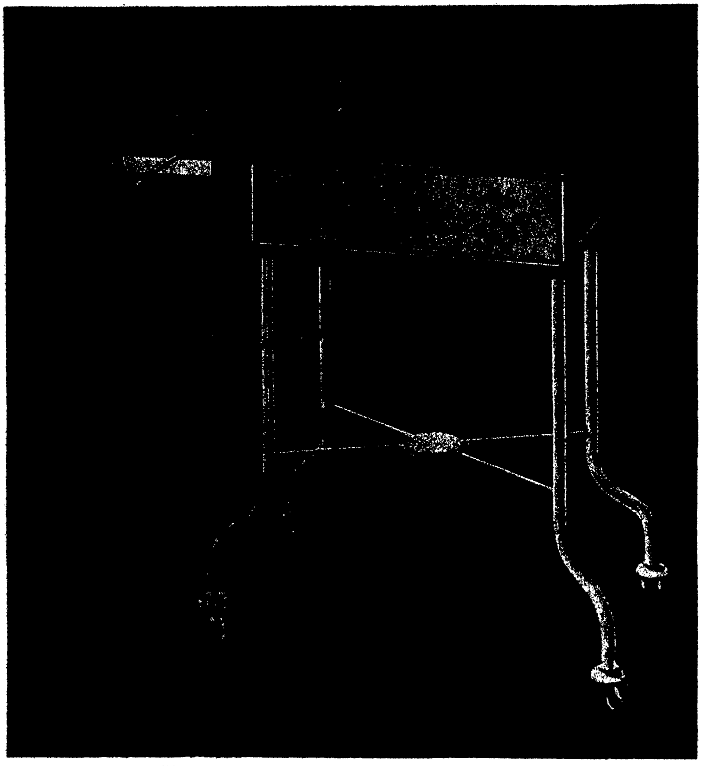

FIG. 165.—The "Moorfields Diatherm."

(1) Surface diathermy (Larsson).
(2) Micro-punctures to close the retinal hole (Weve).
(3) Simultaneous multiple punctures (Safar).

### Apparatus

Diathermic machines of special design are required for the operation. That known as the "Moorfields Diatherm" and made by John Weiss & Sons Ltd., London, is employed at the Moorfields Eye Hospital. It is illustrated in Fig. 165.

A milliamperemeter is a separate component and is connected in series with the active electrode, the current being regulated to give a reading of 60 to 70 milliampères when it is passing through the body.

The indifferent electrode is a perforated zinc plate. It is applied to the forearm, perfect apposition being effected by smearing the skin with saline cream and bandaging the zinc plate securely in position with even pressure and contact.

Insulated retractors are necessary to hold back the lids, conjunctiva and Tenon's capsule.

A metronome is used to indicate the duration of time for which the diathermy is applied.

## The Operation

### *Anæsthetic*

Pantocaine (1 per cent.) is instilled into the conjunctival sac and an injection of 1 c.c. of 2 per cent. novocaine and adrenalin is made into Tenon's capsule over the operation area.

An incision is made through the conjunctiva and Tenon's capsule 9 mm. behind and concentric with the corneoscleral junction, over the area of sclera corresponding with the retinal hole and detachment. The sclera is exposed cleanly and the posterior edge of the conjunctiva and Tenon's capsule retracted by sutures passing through these membranes and fixed by Spencer-Wells forceps to the sterile towel covering the patient's head. A rectus muscle may be divided, after inserting mattress sutures, to facilitate exposure of the sclera in certain areas. A traction suture is passed transversely through the superficial fibres of the sclera in the meridian of the retinal tear at a point about 8 mm. behind the limbus. The ora serrata is marked out approximately by a turn of a trephine through the superficial layers of the sclera 8, 8·5, or 9 mm. behind the corneoscleral junction in hypermetropes, emmetropes and myopes respectively. Care is taken not to apply the active electrode in front of this point owing to the danger of inducing a troublesome cyclitis. Absolute hæmostasis over the area of sclera to be treated is essential. Any bleeding points should be touched with a probe heated in a spirit flame.

Applications of diathermy are then made. There are various ways of applying it.

### (1) *The Larsson Method of Surface Diathermy*

In this method the active electrode is applied firmly to the surface of the sclera over the site of the retinal hole and its vicinity. The current is controlled by a foot switch and should not be turned on until the electrode is firmly applied to the sclera and should be switched off before the electrode is removed. A current of 65 to 70 milliamperes for seven seconds is considered the optimum in the present state of our clinical experience. A faint brownish-grey ring appears at the site of application. Any charring of the sclera is countered by drops of sterile distilled water applied by the assistant. The active electrode is placed on the sclera at points 2 mm. apart over the area it is desired to treat. It is important not to apply the diathermy near a vena vorticosa. Thrombosis in the choroid and intraocular hæmorrhage have been disastrous complications as a result of this. Before evacuating the inter-retinal (sub-retinal) fluid through a trephine hole any divided muscle should be resutured. The trephine is placed at or near the retinal tear or at a site which will be the most dependent when the head is placed so that gravity may operate through the vitreous and press back the retina against the choroid at the site of the retinal tear. The trephine removes a disc of sclera 1·5 mm. in diameter and exposes the choroid without perforating it. Two trephine holes may be made in cases of extensive detachment of the retina with "ballooning" and much inter-retinal fluid. The inter-retinal fluid is then evacuated by passing a

FIG. 166.—Active Electrode used in the Larsson method.

blunt-ended punctum dilator through the choroid. Bleeding from the choroidal vessels is rare, but if this occurs the affected site should be touched with a hot probe. The wound is closed by suturing the conjunctiva and Tenon's capsule, atropine is instilled and a pad and many-tailed bandage applied.

The patient's head is placed in a position where gravity will assist the drainage of inter-retinal fluid and help to appose the detached part of the retina to the area of choroiditis induced by the diathermy.

Absolute immobility of the head in the approved position is desirable for fourteen days at least. The operated eye is kept atropinised for several weeks owing to the danger of iridocyclitis complicating convalescence. After fourteen days dark glasses pasted with black photographic paper leaving a small central aperture 3 mm. in diameter are worn for two or three weeks to prevent unnecessary lateral movements of the eyes.

### (2) *Closure of the Hole by Micro-punctures* (*Weve*)

When the hole is far back Weve employs a unipolar electrode, puncturing the sclera with a fine diathermy needle and using a current of a few milliamperes only for one to three seconds. The operator views the result of his work through a Zeiss contact glass placed over the cornea. With the ophthalmoscope the area of coagulation is seen to be white and fluffy, and its site relative to the tear is a guide to further punctures until the tear is satisfactorily closed. Inter-retinal fluid is lost slowly. The accuracy of this operation is praiseworthy, but the introduction of the needle into the vitreous involves more trauma than the surface diathermy of Larsson.

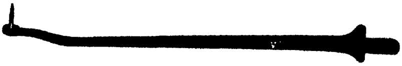

FIG. 167.—Single-needle Electrode.

### (3) *Simultaneous Multiple Punctures* (*Safar*)

Safar employs special electrodes consisting of several insulated needle-points arranged on bars looking like small brushes on handles which fit into the electrode carrier.

These electrodes are held in an insulated forceps "carrier" which is touched by the active diathermic electrode when the needle points are applied to the sclera. The needles are driven through the sclera and enter the choroid. The needle-brushes are implanted in a ring around the retinal tear or in a semicircle around an anterior retinal dialysis and are not removed until the entire area has been thus treated. They are then removed by seizing them with the forceps "carrier" and again applying the active diathermic electrode to this instrument when they can be withdrawn, inter-retinal fluid oozing out through the punctures. The evacuation of this fluid may be further facilitated by aspiration with a blunt-ended syringe needle.

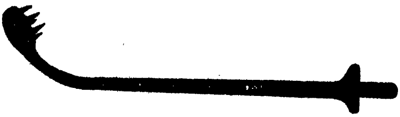

FIG. 168.—Multiple-needle Electrode employed by Safar.

## *Modifications of Safar's Method*

Peter has modified this method by making a barrage of non-insulated micro-pins of platinum-iridium inserted through and around the retinal hole. The micro-pins are fitted with stops so that the sclera also receives a small degree of treatment while the mouth of the outlet is widened, giving better drainage.

Gresser uses non-rusting sewing needles passed through a bakelite disc allowing 2 mm. of the needle to protrude. The holder is made of steel with a brass sleeve. The needles and the holder are magnetic. A current of 20 to 40 milliamperes is used for the insertion of the needles which are placed 4 to 5 mm. apart.

C. B. Walker employs micro-puncture pins with a non-insulated stop. The pins contain 12 to 25 per cent. iridium-platinum and are cleaned by passing through a Bunsen burner on a platinum wire.

Klein recommends the use of micro-pins set in a small rubin plate which acts as a stop when passing the pins through the sclera. He advises a current of 30 milliamperes for two or three seconds during the insertion of the pins.

The pins are placed around the retinal hole and withdrawn at the end of the operation, inter-retinal (sub-retinal) fluid seeping through the scleral punctures and producing effective drainage.

### Results of Diathermic Treatment

The results of treatment of retinal detachment by these methods are better than those of any other procedure. A large number of patients have been treated by Larsson's surface diathermy technique and of these 43 to 58 per cent. have been cured. It is possible that after a lapse of some years during which time recurrences of the retinal detachment may happen these statistics will prove to be too optimistic. Of the other methods of applying surgical diathermy too few cases have so far been treated to afford any reliable statistics.

### Prognosis after Diathermy

The prognosis is better in early cases : when the retinal detachment has not involved the macula ; when there is a single small hole in front of the equator and easily accessible ; when the vitreous and choroid are apparently healthy and the retina does not show signs of degeneration.

Multiple tears, large rents, aphakic eyes, degenerative changes in the retina and vitreous, active choroidal lesions, high myopia and a detachment of long standing generally afford a bad prognosis.

However, owing to the excellent pioneer work of Professor Gonin and to modern advances in technique, particularly in diathermy, much is being done to save the vision of eyes that would be otherwise doomed to blindness.

## NEOPLASMS

Small neoplasms on the lid margin, the limbus, the plica semilunaris and caruncle may be satisfactorily treated by electrocoagulation, a method in which a large indifferent electrode is used and a small needle as the active electrode. A current of 200 to 300 milliamperes for two or three seconds is employed. This method can also be used to form a

" barrage " through the normal tissues beyond a neoplasm previous to its excision.

The excision of large malignant neoplasms and exenteration of the orbit may be effected by the electrode knife. The indifferent electrode is replaced by a branched handle carrying two small electrodes set a short distance apart. An intense heat is generated in the zone between these two electrodes. A current of 500 milliamperes is used.

### CICATRICIAL BANDS

*Cicatricial bands* in a socket after incision of an eye may be effectively divided by a needle hook composed of two electrodes. A current of 200 to 300 milliamperes is passed for two or three seconds, sufficient to turn the cicatricial band white. A temporary prosthesis is inserted immediately. The effect is permanent after fifteen days and the resultant scars are delicate and non-retractile.

### TRICHIASIS

*Trichiasis* is treated by passing a sharp needle into a lash follicle and using a current of 150 milliamperes for one second. It is considerably less painful than electrolysis.

### CATARACT EXTRACTION

Recently Lacarrère and others have attempted intracapsular cataract extraction by introducing a needle into the substance of the lens after the Graefe section has been made, thereby producing electrocoagulation of the adjacent lens fibres. Subsequently manipulations to effect rupture of the suspensory ligament and extraction of the lens in its capsule depend upon the adhesion of the lens to the needle. The lift on the lens by this method is said to be equivalent to 70 gm., which is considerably more than can be obtained by capsule forceps or Barraquer's suction apparatus.

Togby has used a small metal disc with a slight concavity in which are set three needles of non-staining steel at an angle of 60 degrees with the plate. These needles are set in insulating material. This device is introduced into the eye through the Graefe section wound. The needles are guided carefully over the iris and then pressed gently on to the anterior capsule of the lens as the current is turned on. A current of 20 to 30 milliamperes for every needle, *e.g.*, 60 to 90 milliamperes, is recommended by Togby.

There are certain technical difficulties about this method. The instrument introduced into the eye is clumsy and may damage the iris or the cornea. The lens capsule may rupture prematurely and in some cases the electrocoagulation and adhesiveness of the lens to the electrode is insufficient for extraction to be completed neatly.

Intra-capsular extraction is by no means universally favoured by the majority of ophthalmic surgeons. For any surgeons but the best exponents of this operation the risks and difficulties are more than those encountered in the extra-capsular operation. Complications when they do occur in the former are generally very serious and it is by no means certain yet that remote sequelæ such as degeneration of the vitreous and retinal detachment may not be more frequent in cases where the intra-capsular technique has been used.

## LITERATURE

FIGDOR, P. *Brit. Journ. Ophthal.*, xiv., p. 405, 1930.

GIFFORD, H. "Handbook of Ocular Therapeutics," p. 86. Kimpton, London.

GREEVES, R. A. *Trans. Ophthal. Soc. U.K.*, liii., p. 481, 1933.

GRESSER, E. B. *Amer. Journ. of Ophthal.*, xvii., p. 340, 1934.

IREDELL and MEADOWS-RYLEY. *Proc. Roy. Soc. Med.*, xii., p. 31, 1918.

JESS, A. *Deut. Ophthal. Gesell.*, xlix., p. 111, 1932.

KLEIN, M. *Trans. Ophthal. Soc., U.K.*, lv., p. 84, 1935.

LACARRÈRE. *Klin. Monats. f. Augenheilk.*, lxxxviii., p. 778, 1932.

LARSSON. *Acta. Ophthal.*, iii., p. 319, 1926.

LAW, F. W. *Trans. Ophthal. Soc. U.K.*, liii., p. 474, 1933.

LOFFLER and WELLISCH. *Klin. Monats. f. Augenheilk.*, lxxxiii., p. 285, 1929.

MADDOX, E. E. *Brit. Journ. Ophthal.*, xvii., p. 161, 1933.

MARTIN, J. E. *Brit. Journ. Ophthal.*, xix., p. 48, 1935.

MONBRUN and CASTERAN. "La Haute Frequence en Ophtalmologie," Paris, 1929.

PETER. *Amer. Journ. Ophthal.*, xvii., p. 924, 1934.

TOGBY, A. F. *Bull. Ophthal. Soc. Egypt*, xxvi., p. 20, 1933.

WALKER, C. B. *Trans. Amer. A.M.A.*, p. 300, 1933.

### *Note on the Use of Electrodesiccation*

The author of the present volume would recommend the value of electrodesiccation in the treatment of innocent neoplasms of the lids and xanthelasma palpebrarum. The absence of pain after the treatment, the trifling reaction, the non-development of œdema, and the formation of permanently soft non-contracting scars, render this form of electrothermic treatment particularly useful for the diseases just mentioned.

In the treatment of xanthelasma an anæsthetic should be injected under the skin of the eyelid. Very short sparks are employed. They are directed for a few moments over the xanthelasma. The overlying epithelium can then be peeled off. The pigmented tissue is sparked and the dried bits picked off until it is entirely removed. After the operation there is a slight swelling. A scab forms at the site of the operation. It separates after about a week. During this time the patient suffers little, if any, discomfort.

# CHAPTER XLVII

## SURGICAL ELECTROTHERMIC METHODS IN DISEASES OF THE RECTUM

### Hæmorrhoids

VARIOUS electrothermic methods can be used for the destruction and removal of hæmorrhoids, and different methods of performing the operation have been described. Little has been reported on the subject by English workers, but in the United States the new methods have been described in various books and periodicals on physiotherapy, and seem to be more widely used than in Europe. In the absence of any standardisation of methods a brief description of the procedure of some operators will be given.

Dr. Turrell,[1] of Oxford, paints the protruded piles with 5 per cent. solution of novocaine or injects 1 per cent. solution of the same substance around the anus. The piles are then coagulated by diathermy. The current is gradually increased until the pile under treatment acquires an ashen-grey appearance or actually bursts by expansion of the heated gases in its interior. The current should not exceed 300 milliamperes.

A considerable amount of swelling of the surrounding tissues and some pain usually follow the operation, and Dr. Turrell advises that the patient should be kept quiet, but not necessarily in bed, for ten days.

Professor Bordier,[2] of Lyons, recommends a light general anæsthetic. He coagulates the external or prolapsed internal piles by the diathermic current. He states that the patients suffer some pain when the coagulated parts are sloughing away and that it is occasionally necessary to apply morphine suppositories.

The late Dr. W. L. Clark, of Philadelphia, originally practised his method of electrodesiccation for the treatment of hæmorrhoids. In a contribution to the *American Journal of Electrotherapeutics and Radiology* [1] he described the following methods.

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[1] "The Principles of Electrotherapy and their Practical Application," Oxford Medical Publications.

[2] "Diathermie et Diathermothérapie," Baillière & Fils, Paris.

In the case of external hæmorrhoids a local anæsthetic was given and a line of desiccation drawn across each pile, instead of a primary incision with a scalpel. The needle electrode was then inserted into the clot, which was desiccated and the vein destroyed. The hæmorrhoid was then incised through the desiccated line without hæmorrhage and the desiccated clot curetted out. Relief was immediate and healing rapid.

In the case of internal piles the sphincter was infiltrated with a 2 per cent. solution of novocaine containing a little adrenalin. Two to three c.c. were injected. The anus was then dilated and each pile in turn drawn down by tenaculum forceps, grasped at its base by a clamp and desiccated. The clamp was then removed. Hæmorrhage did not occur.

Dr. Clark said that the post-operative discomfort was so slight that patients could proceed with their duties of life immediately after the operation, but that this was not advisable if the case were a bad one. A rest in bed for a few days should then be ordered.

By the courtesy of Dr. Bierman the author was able to see the performance of the operation on one of his private patients in New York. The patient was placed in the lithotomy position and the anal sphincter was infiltrated with novocaine and adrenalin. The anus was then dilated and the hæmorrhoids brought into view. Sparks of 1 in. or 1½ in. were directed on each pile in turn. The active electrode was connected to an Oudin resonator, the patient being earthed. The piles gradually shrunk in size and were converted into small dried masses of tissue.

Dr. Bierman devised a special clamp for grasping hæmorrhoids at their base and the passage of diathermic current between the jaws of the clamp.[2] In this way the piles can be sealed at the base and removed.

Of the different methods the best appear to be those in which the hæmorrhoids are sealed at the base by diathermy and then removed. They resemble the clamp and cautery method, but the sealing is more effective and there is little cicatricial contraction after healing. Those who have had experience say that a soft non-contracting scar is left after desiccation. Dr. Wyeth[1] states that the treatment of hæmorrhoids by desiccation "cannot be too highly commended to the surgeon who has long wished for an operation for the removal of hæmorrhoids which is quick and clean, unaccompanied by hæmorrhage or shock, and which leaves the tissues soft and pliable."

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[1] Vol. XLIII., No. 9, September, 1925.

[2] *Physical Therapeutics*, Vol. XLV., No. 1, January, 1927.

If internal or prolapsed hæmorrhoids are coagulated and allowed to slough spontaneously there is always the likelihood of pain and swelling for a few days after the operation.

The writer's experience in the treatment of hæmorrhoids by surgical diathermy is limited to a few cases. In some of these the hæmorrhoids were permanently prolapsed and contained much fibrous tissue. They were coagulated by diathermy under local anæsthesia, and the patients suffered little or no discomfort after the operation. In 2 cases in which the hæmorrhoids had been of less long duration there was considerable pain for a few days after the operation. Both patients, however, had suffered considerably *before* the treatment. The final result was complete relief. In another case there were three permanently prolapsed piles but no pain. Each was treated by a special bi-polar needle electrode. The two needles were mounted on a holder and connected to the two terminals of the diathermic machine. The needles were inserted into one of the piles and the current increased to the limit of toleration. The patient suffered no further discomfort. Three weeks later the pile had disappeared. The second and third were treated in the same way with the same results.

### Papillomata of the Rectum and Colon

The case described below is an example of the usefulness of diathermy in the treatment of multiple papillomata of the rectum and colon. The case was treated by the late Andrew Fullerton, formerly surgeon to the Royal Victoria

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[1] "Treatment of Neoplastic Diseases by Electrothermic Methods," p. 199, Paul B. Hoeber, New York.

Hospital, Belfast, who kindly described the details to the writer and gave permission for their publication.

The patient, a woman of 28, had suffered for two or three years from occasional pain in the abdomen and irregular action of the bowels. At times she had passed blood by the bowel, sometimes mixed with matter. On examination with the sigmoidoscope a small papilloma, about the size of a split-pea, was seen in the rectum, about 2 to 3 cm. up. It was shaved off. Two or three more papillomata, about the same size, were seen between the first one and a point 10 cm. higher up. The removed papilloma was examined. The section showed that it was simple and resembled an adenoma.

On May 11th, 1925, five papillomata were destroyed by diathermy through the sigmoidoscope. The highest was about 15 cm. from the anus.

On June 26th, 1925, the sigmoidoscope revealed no papillomata. The bowels were loose and occasionally a little blood was passed.

On October 21st, 1925, a papillomata about the size of a pea, and with a short pedicle, was seen about 17 cm. up. It was destroyed by diathermy.

On February 13th, 1926, no papillomata were seen. The diarrhœa was less.

On May 15th, 1926, a papilloma, about the size of a marble, was seen about 20 cm. up. It was destroyed by diathermy.

On July 2nd, 1926, the treatment was repeated. The patient complained later of cramp-like pains in the abdomen, and the stools continued to be loose.

On August 9th, 1926, laparotomy was performed. A large fleshy mass was felt in the pelvic colon. The bowel above this was somewhat dilated. Other smaller round soft masses could be felt as far back as the cæcum. The large intestine and about 4 in. of the small intestine were removed. A lateral anastomosis was made between the ileum and rectum.

On slitting up the portion of bowel removed there were found a large number of sessile polypi varying in size from that of a hemp seed to that of a marble. One large conglomerate mass was found in the pelvic colon measuring 3½ in. by 2½ in. These papillomata were pink in colour and closely resembled those commonly found in the bladder. A portion of the large tumour was examined by Professor Symmers and pronounced to be papillomatous adenoma.

The patient went home on September 28th, 1926, feeling very well and passing semi-solid motions twice a day.

On January 26th, 1927, the sigmoidoscope was passed. The rectum was free from papillomata. The patient was last heard of in March, 1927 (a few days before the case was described). Though not strong she was able to get about and was comfortable.

Commenting on this case Mr. Fullerton stated that the treatment of the rectal papillomata by diathermy enabled him to preserve the rectum up to the point of anastomosis—a very important fact from every point of view.

# CHAPTER XLVIII

# SURGICAL ELECTROTHERMIC METHODS IN DISEASES PECULIAR TO WOMEN

## Breast

### (a) *Ineradicable Cases*

CASES of advanced carcinoma mammæ in which the breast is extensively infiltrated and presents ulcers or fungating masses of growth are suitable for electrocoagulation if cachexia is not present. Not many cases of this kind have been treated by diathermy. The author has had experience of 5: in 2 the results were striking. The following is a *résumé* of the particulars of the cases, the treatment and the subsequent history.

*Case* 1.—The patient, a lady of 45, came under the author's care in November, 1921, suffering from Paget's disease of the nipple. She was thin and fragile and the subject of advanced but quiescent rheumatoid arthritis. In addition to the eczema of the nipple there were large movable masses in the breast. The eczema disappeared under X-ray treatment. The patient refused surgical treatment and would not consent to receive a general anæsthetic. The swellings in the breast gradually enlarged and became adherent to the skin. The latter ulcerated, and fungating masses of growth appeared. Resisting X-ray treatment they increased in size, and there developed a large fungating mass measuring 7 in. by 4 in. and projecting 1½ in. from the surface.

Coagulation by diathermy was then commenced. The growth was destroyed, piece by piece, at successive operations, until it projected no more than about ½ in. from the surface. Up to this period the patient did not feel undue heat during the coagulation. A disc-electrode measuring 5 mm. in diameter was used. To enable the continuation of the coagulation a local anæsthetic was given, and the remainder of the growth was treated together with the skin at the edges. In June, 1925, the greater portion of the chest wall formerly occupied by the growth was covered by scar tissue. Two slightly elevated masses remained: these measured, respectively, 1¾ in. by 1¾ in. and ½ in. by ½ in. These were covered by a dusky epithelium. Since the date last stated the patent attended irregularly and infrequently by reason of changes of residence to localities at a distance from London. As a result, the growth increased in size, and at the time of writing (February, 1927) measured 3 in.

by 2¾ in. Its maximum elevation was about ½ in. from the surface. Apart from occasional pain in the joints the patient's general health did not retrogress and her weight did not decline.

The difficulties attending the treatment of this case were increased by the fact that the patient would not receive a general anæsthetic, and that the serious nature of her disease had to be withheld from her knowledge.

*Case* 2. F. P., aged 50. In this case the breast had been amputated at an earlier date, but the growth had reappeared in the scar. When the patient came for treatment there was a very large mass of new tissue, "of the size of a cocoanut," on the front of the chest, in the region of the original scar. In November, 1913, the mass was treated by diathermy. A narrow-blade electrode was used and the growth cut away. The base and edges were then coagulated, a disc electrode being used. The coagulated tissue sloughed away and the skin began to grow over the denuded area. Eleven weeks later the only uncovered portion was a small area measuring about 1½ in. in diameter. Signs of recrudescence were present in this part. The latter was coagulated by diathermy.

The patient wrote on February 11th, 1915, that is, fifteen months after the first application of diathermy, to say that the part was completely covered by smooth skin, except for one minute area, the size of a pin's head, from which a discharge occasionally appeared. There was no pain or swelling.

The case was under the care of Sir D'Arcy Power.

In the 3 remaining cases the affected breasts were completely occupied with malignant growth and the skin was adherent. Ulceration was present in one, and in another there were fungating masses. In all the cases the axillary glands were much enlarged.

In each case the entire breast was coagulated by diathermy. A disc electrode, 15 mm. in diameter, was used. After each stratum of tissue was coagulated it was cut away by the scalpel and the bleeding from severed vessels was stopped by the needle electrode.

Two of the patients were surprisingly free from pain and discomfort after the operation. The wounds commenced to heal. In one case the healing was nearly complete, the unhealed area measuring 1¼ in. by 1 in. The patient then developed pneumonia and died. The other patient left hospital when healing had proceeded to the same extent.

In the third case healing did not commence. Hæmorrhages were frequent and the patient died two months later. At the autopsy visceral metastases were found.

At a discussion on Surgical Diathermy held at the Royal Society of Medicine, in December, 1926, Mr. H. H. Rayner, surgeon to the Royal Infirmary, Manchester, stated that he had had experience of diathermy in cases of carcinoma of the breast that were plainly inoperable. The cases were of the type which presented massive growth either fungating through the skin or about to ulcerate through. Such cases were substantially benefited by diathermy. If there were no internal metastases and no massive enlargement of the axillary glands the patients lived an active life for two to three years.

At the same meeting Mr. Gordon-Taylor, surgeon to the Middlesex Hospital, gave his experience on the treatment of malignant disease of the breast. He described a very interesting case of advanced carcinoma mammæ which he had treated by diathermy three years previously. She had a horrible carcinoma of the breast which had been treated by herbalists and others. She summoned her doctor only because she had had alarming hæmorrhage. When she was brought to the nursing home she was nearly dead. Her breast was removed by diathermy, and she was transfused. There were no enlarged glands at the time. She recovered. Three years after the operation she was still well.

### (*b*) *Eradicable Cases*

Important pioneer work on the surgical treatment of malignant disease of the breast by the cutting arc, *i.e.*, by electrosection, was conducted by the late John Anderson, surgeon to the Royal Infirmary, Dundee. He employed the cutting arc in place of the scalpel for the radical amputation of the breast. He used a scalpel, however, for the small area immediately over the axillary vessels and nerves. The arc was not used for the following reason ; it has already been stated that the excitable tissues are momentarily stimulated when the arc is struck in close vicinity to them. The stimulation of the nerve trunks in the axilla would cause jerking movements of the arm which might bring the main axillary vessels, or the nerve trunks themselves, in contact with the arc, and inflict serious damage on them.

The bleeding which occurred from the vessels which the arc did not seal was stopped by a diathermic current in the manner already described (p. 438). The skin flaps, which had been dissected back by the arc, did not lose their heat. They were brought together and sutured in the ordinary way. Healing by first intention occurred.

Anderson found that the general condition of the patients was better after electrosection than after the use of the scalpel. He also found that the healing was as good after use of the arc as it was after cutting by the scalpel. He felt convinced that the sealing of the lymphatics at the time of their division by the arc greatly lessened the chance of dissemination of the disease. He was convinced that electrosection had no disadvantages in comparison with scalpel surgery. The patients suffered little pain or shock after the operation. Less blood was lost and the body heat was maintained.

Anderson's work was carried on over a period of thirteen years and ended with his untimely death in 1935.

A lengthy experience in the treatment of cancer of the breast by electrothermic methods has been acquired by W. Sampson Handley. Encouraged by the results which he had obtained in ineradicable cases, he began to practise electrosection in cases which would otherwise have been dealt with by the scalpel. Discussing the subject at a meeting of the Medical Society of London,[1] after the presentation of a paper on the uses of diathermy in medicine and surgery, he said that he had employed the electrothermic methods almost exclusively since 1927 for breast cancer. He had found that the use of the cutting current eliminated the risk of chill and the difficulty of keeping the flaps warm. The absence of shock after electrosection was no less noteworthy in his experience than in that of John Anderson.

At the same meeting Mortimer Woolf advocated the use of diathermy for operations on carcinoma of the breast. For two years he had operated on all his cases of this disease by the cutting current, and he was convinced that the results were infinitely superior, both in regard to the absence of shock and the general well-being of the patient, to those obtained by means of the scalpel. The operation also was more quickly performed.

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[1] *Transactions of the Medical Society of London*, Vol. 54.

Gordon-Taylor used Anderson's method in the treatment of 15 cases of malignant disease of the breast. He found that the condition of the patients was good after they left the operating table. The facility with which the bleeding could be stopped was striking and he found that it shortened the duration of the operation. He thought that the employment of the cutting arc held out considerable advantages over the ordinary surgery with the knife.

The use of electrosection in the treatment of cancer of the breast has not been adopted by a sufficient number of surgeons or practised over a period long enough to enable a true prophecy to be made as to the position which the new method will ultimately occupy. It is not too much to say, however, that the use of the cutting arc is an important advance in the surgical treatment of cancer of the breast.

### Female Genitalia

The surgical electrothermic methods seem to have been used least of all in the treatment of growths of the female genitalia. Comparatively little experience was gained in the days before the use of radium had been fully investigated. At the present time the popularity of deep X-ray and radium therapy has relegated electrothermic treatment to the background.

A brief account of the results obtained in the earlier days is given below.

The author treated 12 cases of malignant growth of the female genitalia by diathermy. All were too advanced for surgical excision. In 10 cases the growth arose from the cervix uteri; in 1 from the vagina, and in another from the right labium majus and part of the left. In all of the cases of carcinoma of the cervix, the growth had spread into the pelvic cellular tissue, so that parts of it could not be reached from the vagina by the electrode; and in the regions where it had spread into the wall of the rectum or bladder, coagulation could not be produced for fear of injury to these organs. The most that could be expected was destruction of the primary focus and its subsequent replacement by granulation tissue and epithelium, so as to abolish hæmorrhage and discharge.

In all the cases, save one, the results of the operation were not satisfactory. The patients did not derive much relief of pain and the bleeding was not stopped. The best result was obtained in a case (described below) of inoperable cancer of the cervix and vagina.

S. S., aged 55. In the situation of the cervix there was an ulcerated excavated mass, with hard and everted edges. The vaginal wall was involved posteriorly, and the posterior left fornix was obliterated completely. Definite induration extended to the pelvic wall and to the utero-sacral folds as far as the bowel. Diathermy was applied in August, 1913, to the parts of the growth that were accessible from the vagina. The patient left hospital nine days later. The slough had not then entirely separated, but the whole of the vaginal mass previously felt had entirely gone and the vaginal wall was covered with smooth tissue.

This patient came at intervals to the out-patient department, and no hæmorrhage or discharge was seen, and no ulceration. The induration previously felt in the pelvic ligaments remained. She was last seen in June, 1914 (ten months after the diathermy), and could not be afterwards traced.

Diathermic coagulation seems to be of value in the preliminary treatment of operable carcinoma of the cervix, before the Wertheim operation, in place of an initial application of zinc chloride or formalin. It was applied to a case of carcinoma of the cervix on June 23rd, 1913. On July 1st a Wertheim operation was commenced, but could not be completed on account of the extensive spread of the growth within the pelvis. The part of the cervix to which the diathermy had been applied was found to be firm, like scar tissue, and no hæmorrhage was caused by its manipulation or incision, and there was no discharge. This patient lived till February, 1914.

J. D. Barris treated a few cases of carcinoma of the cervix by diathermic coagulation prior to hysterectomy. In one of the cases a highly vascular fungating growth projected from the cervix into the vagina. The fungating portion and base were subjected to diathermy. The coagulated tissue sloughed away and hysterectomy was performed at a later date.

Nagelschmidt describes (" Lehrbuch," 1st edition, p. 277) the excision of a uterus after diathermic coagulation of a carcinoma of the cervix. After laparotomy had been performed and the intra-abdominal part of the operation had been completed, a mass of bleeding new growth attached to the cervix was completely coagulated by diathermy applied *per vaginam*. The body of the uterus was grasped by the hand of an assistant so as to give warning of excessive heating of the part held and other parts in the abdominal cavity. This excessive heating, however, did not occur. After complete coagulation of the cervix the vagina was rinsed out and dried, and the uterus, with the remains of the cervix, were removed, as a sterile body, through the abdominal wound.

# APPENDIX

DIATHERMY has been used by George Crile, of Cleveland, Ohio, both for the prevention of shock during operation and for its treatment after operation. For the first purpose the liver is subjected to diathermy during the performance of the operation, the object desired being the warming of the blood after its temperature has been lowered in its passage through the exposed abdominal viscera.

For the second purpose general diathermy is administered, one electrode being applied to the head, and two others to the feet.

The reference to the use of diathermy by Crile for shock can be found in *Surgery, Gynæcology and Obstetrics*, February, 1926, p. 218.

Professor A. W. Sheen, of Cardiff, has used diathermy, with apparent benefit, during two abdominal operations. It was applied to the liver in order to warm the portal blood.

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